This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Digitized by Google

Stanford University Libraries
3 6105 006 924 992

BRANNER
GEOLOGICAL LIBRARY

STANFORD UNIVERSITY LIBRARIES

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

THE

Mineralogical Magazine

AND

JOURNAL

OF THE

MINERALOGICAL SOCIETY.

VOLUME XII.

LONDON:
SIMPKIN, MARSHALL, HAMILTON, KENT & Co., LIMITED,
STATIONERS' HALL COURT.

MDCCCC.

Digitized by Google

214669

London:
Printed by Williams & Strahan,
7 Lawrence Lane, Cheapside.

Digitized by Google

TABLE OF CONTENTS.

PAGE

Augelite from a New Locality in Bolivia. By L. J. Spencer, M.A., F.G.S., Assistant in the Mineral Department of the British Museum 1

Stanniferous Argyrodite from Bolivia: The Identity of the so-called "Crystallised Brongniardite" with Argyrodite-Canfieldite. By G. T. Prior, M.A., F.G.S., and L. J. Spencer, M.A., F.G.S., Assistants in the Mineral Department of the British Museum 5

Atacamite from Sierra Gorda, Chili. By G. F. Herbert Smith, B.A., Assistant in the Mineral Department of the British Museum... 15

On Sphærostilbite. By G. T. Prior, M.A., F.G.S., Assistant in the Mineral Department of the British Museum 26

On Senaite, a new Mineral belonging to the Ilmenite Group, from Brazil. By Dr. E. Hussak, of the Geological Survey of S. Paulo; and G. T. Prior, M.A., F.G.S., Assistant in the Mineral Department of the British Museum 30

Note on peculiar Quartz-Pseudomorphs found at the Owera Mine, Opitonui, North Island, New Zealand. By Prof. G. H. F. Ulrich, F.G.S. [Communicated by Prof. Judd, C.B., F.R.S.] 33

Notes and Comments 35

Obituaries. Alfred Olivier Des Cloizeaux 37

Emeritus-Professor M. Forster Heddle, M.D., F.R.S.E. 38

Albrecht Schrauf 42

Reviews 43

Abstracts 45

Plagionite, Heteromorphite and Semseyite as Members of a Natural Group of Minerals. By L. J. Spencer, M.A., F.G.S.; with Analyses by G. T. Prior, M.A., F.G.S.; Assistants in the Mineral Department of the British Museum 55

Digitized by Google

PAGE

Petrographical Notes on the Rock-specimens collected in Antarctic Regions during the voyage of H.M.S. *Erebus* and *Terror* under Sir James Clark Ross, in 1839-43. By G. T. Prior, M.A., F.G.S., Assistant in the Mineral Department of the British Museum... 69

Riebeckite in Trachytic Rocks from Abyssinia. By G. T. Prior, M.A., F.G.S., Assistant in the Mineral Department of the British Museum 92

Minerals from Swaziland: Niobates and titanates of the rare earths, chemically allied to Euxenite and Fergusonite; Cassiterite, Monazite, &c.; the "Æschynite" from Hitterö. By G. T. Prior, M.A., F.G.S., Assistant in the Mineral Department of the British Museum 96

On some lead minerals from Laurium, namely, Laurionite, Phosgenite, Fiedlerite, and (new species) Paralaurionite. By G. F. Herbert Smith, B.A.; with Chemical Analysis by G. T. Prior, M.A., F.G.S., Assistants in the Mineral Department of the British Museum 102

Communications from the Oxford Mineralogical Laboratory. I. Mineralogical Notes: Zinc-Blende; Galena; Pyrites; Lead. By Prof. H. A. Miers, M.A., F.R.S.; with Analyses by E. G. J. Hartley, B.A.... 111

Note on the Crystals of Lead described in the preceding communication. By Allan Dick 118

II. On the constitution of the mineral Arsenates and Phosphates. By E. G. J. Hartley, B.A. 120

Reviews 123

Obituary. Andreas Arzruni 129

Abstracts 130

On a new mode of occurrence of Ruby in North Carolina. By Prof. J. W. Judd, C.B., LL.D., F.R.S., V.P.G.S., and W. E. Hidden, F.G.S.; with Crystallographic Notes by Dr. J. H. Pratt 139

On the Crystallography of the Rubies from Macon County, North Carolina. By Dr. J. H. Pratt... 150

Digitized by Google

PAGE

Communications from the Oxford Mineralogical Laboratory: On the constitution of the natural Arsenates and Phosphates. Part II. Pharmacosiderite. By E. G. J. Hartley, B.A. ... 152

On Langbeinite from the Punjab Salt Range. By F. R. Mallet, F.G.S., late Superintendent, Geological Survey of India ... 159

On a mass of Meteoric Iron from the neighbourhood of Caperr, Rio Senguerr, Patagonia. By L. Fletcher, M.A., F.R.S., Keeper of Minerals in the British Museum 167

On the Cliftonite and Tænite of the Meteoric Iron found in 1884 in the Sub-district of Youndegin, Western Australia. By L. Fletcher, M.A., F.R.S., Keeper of Minerals in the British Museum... 171

A Three-Circle Goniometer. By G. F. Herbert Smith, B.A., Assistant in the Mineral Department of the British Museum ... 175

Note on the Identity of Paralaurionite and Rafaelite. By G. F. Herbert Smith, B.A., Assistant in the Mineral Department of the British Museum 183

The Identity of Binnite with Tennantite; and the Chemical Composition of Fahlerz. By G. T. Prior, M.A., F.G.S., and L. J. Spencer, M.A., F.G.S., Assistants in the Mineral Department of the British Museum 184

Review 214

Abstracts 215

Communications from the Oxford Mineralogical Laboratory: On the constitution of the natural Arsenates and Phosphates. Part III. Plumbogummite and Hitchcockite. By E. G. J. Hartley, B.A. 223

Communications from the Oxford Mineralogical Laboratory: On the constitution of the natural Arsenates and Phosphates. Part IV. Beudantite. By E. G. J. Hartley, B.A. 234

Communications from the Oxford Mineralogical Laboratory: Note on the Hitchcockite, Plumbogummite and Beudantite analysed by Mr. Hartley. By Professor H. A. Miers, M.A., F.R.S. ... 239

Digitized by Google

PAGE

On Florencite, a new hydrated Phosphate of Aluminium and the Cerium Earths, from Brazil. By Dr. E. Hussak, of the Geological Survey of S. Paulo; and G. T. Prior, M.A., F.G.S., Assistant in the Mineral Department of the British Museum 244

On Hamlinite, Florencite, Plumbogummite (Hitchcockite), Beudantite and Svanbergite, as members of a natural group of minerals. By G. T. Prior, M.A., F.G.S., Assistant in the Mineral Department of the British Museum 249

On Ægirine and Riebeckite Anorthoclase Rocks related to the "Grorudite-Tinguaite" series, from the neighbourhood of Adowa and Axum, Abyssinia. By G. T. Prior, M.A., F.G.S., Assistant in the Mineral Department of the British Museum ... 255

On Stokesite, a new mineral containing tin, from Cornwall. By A. Hutchinson, M.A., Demonstrator of Mineralogy in the University of Cambridge 274

On Sulpharsenites of Lead from the Binnenthal. By R. H. Solly, M.A.; with Analyses by H. Jackson, B.A., B.Sc. 282

Obituaries. Carl Friedrich Rammelsberg 298

Geheimrath Professor Dr. Geinitz 300

James Reynolds Gregory 301

Reviews 302

Abstracts 305

Petrographical Notes on the Rock-Specimens collected in the Little Island of Trinidad, S. Atlantic, by the Antarctic Expedition of 1839-43, under Sir James Clark Ross. By G. T. Prior, M.A., F.G.S., Assistant in the Mineral Department of the British Museum... 317

On some remarkable composite crystals of copper pyrites from Cornwall. By Prof. W. J. Lewis, M.A., and A. L. Hall, B.A. 324

On Grassmann's method of axial representation, and its application to the solution of certain crystallographic problems. By W. J. Lewis, M.A., Professor of Mineralogy in the University of Cambridge 333

Digitized by Google

PAGE

On the determination of the positions of points and planes after rotation through a definite angle about a known axis. By R. W. H. T. Hudson, B.A. Communicated by Prof. W. J. Lewis, M.A. 343

Communications from the Oxford Mineralogical Laboratory. 1. On a Rhombic Pyroxene from South Africa. 2. On a method of illustrating the variation of thermal conductivity of crystals in different directions. 3. A twin crystal of Sapphire. 4. On Monazite and associated minerals from Tintagel, Cornwall. By H. L. Bowman, M.A., Demonstrator in Mineralogy 349

Conchite, a new Form of Calcium Carbonate. By Agnes Kelly. (Communicated by Prof. H. A. Miers)... 363

The alteration of Pyrite by underground water. By John W. Evans, LL.B., D.Sc., formerly State Geologist in Mysore ... 371

A List of New Mineral Names. By L. J. Spencer, M.A., F.G.S., Assistant in the Mineral Department of the British Museum ... 378

Notes and Comments 395

Review 397

Index 399

Errata 407

Digitized by Google

Digitized by Google

THE MINERALOGICAL MAGAZINE
AND
JOURNAL
OF THE
MINERALOGICAL SOCIETY.

No. 54. JUNE, 1898. Vol. XII.

Angelite from a New Locality in Bolivia.

By L. J. Spencer, M.A., F.G.S.,
Assistant in the Mineral Department of the British Museum.

[Read November 16th, 1897.]

In a recent number of this Magazine (Vol. XI, 1895, p. 16) angelite was shown to be a definite mineral species, having the chemical composition $AlPO_4.Al(OH)_3$, and crystallising in the monosymmetric system. Owing to its rarity, or perhaps to its similarity in appearance to barytes, it has previously only been described[1] three times in mineralogical literature, and has been found at only two localities, namely, Westaná in Sweden and Machacamarca in Bolivia. It is therefore of interest to be able to record the mineral from a new locality.

The new occurrence is in the veta [=vein] Carmen of the silver mines at Tatasi and Portugalete,[2] in the province Sud-Chichas of the department Potosi. The specimen on which the angelite was found is one of a

[1] Des Cloizeaux (*Manuel de Min.* II, 1893, p. 454) examined cleavage flakes of the Swedish mineral; he gives a cleavage angle and some of the optical characters, but not enough to determine the system of crystallisation.

[2] Tatasi and Portugalete are mining villages which are connected by a level driven through the intervening mountain. H. Reck has described the Portugalete mines, *Berg.-und Hüttenm. Zeitung*, 1884, p. 125.

Digitized by Google

large suite of Bolivian specimens recently presented to the British Museum by my friend Mr. Malcolm Roberts, A.R.S.M., Administrator of Mines to the Compañia Guadalupe de Bolivia.

The specimen consists of an altered, acid volcanic tuff, with massive pyrites, and in cavities a considerable quantity of "feather ore," which is often aggregated in balls around indistinct crystals of black blende. In the cavities are also crystals of pyrites, chalybite, gypsum and calcite, together with white, powdery kaolin. The pyrites is cubical in habit, but sometimes aggregates of small cubes build up indistinct octahedra, as in fluorite. The gypsum is present as a few colourless needles with the forms $b\{010\}$, $m\{110\}$, $l\{111\}$ and $n\{\bar{1}11\}$. Calcite occurs as very minute thick-tabular crystals, with smooth, bright prism planes, and dull, rounded basal planes; they incrust the pyrites, or are penetrated and supported by the needles of "feather ore." In the kaolin a trace of phosphoric acid was found. The "feather ore," which is locally known as "paja quemada" (= burnt straw), consists of radiated or confused masses of very fine needles or hairs, which possess a certain degree of flexibility, and are of a dull iron-black colour. It was found to contain lead, antimony and sulphur. An analysis of "paja quemada" from Portugalete has been made by L. Kiepenheuer, and from this vom Rath[1] deduces the formula $2(Pb^{3}_{5},Fe^{2}_{5})S+Sb_2S_3$, calling the mineral jamesonite. Some of Mr. Roberts' specimens are, however, so intimately mixed with numerous minute octahedra of pyrites, as to suggest that the iron shown in Kiepenheuer's analysis may be due to the presence of this mineral.

The augelite, which is present in only small amount, is usually embedded in the massive pyrites, and sometimes encloses specks of this mineral. It is colourless and transparent, and shows the usual perfect cleavages. It so closely resembles barytes in general appearance, that it is only to be distinguished from this species by the measurement of the cleavage angles, and by the optical examination of cleavage flakes, namely, the determination of the extinction angles and the position of the optic axes. In a cavity, two small crystals showing faces and a third crystal very deeply etched were found; these measured about 1 mm. across.

One of these crystals shows three large bright planes, namely, $m(110)$, $m'''(1\bar{1}0)$, and a vicinal face near $c(001)$ in the zone $[001, 1\bar{1}0]$. The presence of this vicinal face, which is striated parallel to its intersection with $(1\bar{1}0)$, quite masks the symmetry of the crystal. Replacing the three edges formed by the above planes are narrow, striated, and some-

[1] *Sitz.-ber. niederrhein. Ges. Bonn*, 1879, XXXVI, p. 80.

Digitized by Google

what ill-defined planes of the forms $a\{100\}$, $n\{112\}$, and $d\{334\}$. The last of these has been previously given only as doubtful. The measured angles were:—

		Calculated.	Measured.
$mm''' = 110 : 1\bar{1}0$	...	113°14′	113°16′
$cm = 001 : 110$	...	77 52½	78 55
$cm''' = 001 : 1\bar{1}0$	...	77 52½	76 16
$dm = 334 : 110$	...	37 41	37 23
$n'm''' = 1\bar{1}2 : 1\bar{1}0$	...	46 45	47 1

The second crystal is also bounded by three large planes, namely, $m'(\bar{1}10)$, $m''(\bar{1}\bar{1}0)$, and a vicinal face quite close to $c(001)$, but in this case perpendicular to the plane of symmetry, and striated parallel to the axis of symmetry. The prism planes, as on the first crystal, are striated parallel to their mutual intersection, that is, parallel to the vertical axis. The new form $g\{910\}$ is represented by three narrow indistinct planes; $x\{\bar{1}01\}$ is present as a mere point, and there are small doubtful planes near the positions of $(\bar{1}16)$ and $(\bar{8}01)$. The angles measured on this crystal were:—

		Calculated.	Measured.
$m'm'' = \bar{1}10 : \bar{1}\bar{1}0$	...	113°14′	113°24′
$cm' = 001 : \bar{1}10$	...	102 7½	101 57
$cm'' = 001 : \bar{1}\bar{1}0$	...	102 7½	101 55½
$gm = 910 : 110$	...	47 3	47°, 47°, 47¼°

With this crystal the indices of refraction, as measured through the natural prism, were 1·5752 and 1·5893 for sodium light; and the optic axial angle[1] in air as seen through the basal plane $c(001)$, was determined with a microscope-stage goniometer devised by Prof. Miers to be 82½°.

Cleavage fragments, which had been goniometrically and optically determined, were found to have the chemical characters of augelite. The specific gravity of the crystals was determined to be 2·69, by the method previously mentioned in this Magazine (Vol. XI. p. 186).

In the previous paper on the augelite from Machacamarca, Bolivia, it was stated that there are three places called Machacamarca in Bolivia,

[1] The acute bisectrix makes an angle of 11½° with the normal to $c(001)$. In the previous paper (*loc. cit.* p. 20) there is a slight ambiguity as to the position of the acute bisectrix. It lies "in the acute angle β," when β is taken as defined by Maskelyne (*Crystallography*, 1895, p. 436), but according to other authors this should read "in the obtuse axial angle β." According to Dana's notation (*System of Mineralogy*, 6th ed. 1892, p. xxxvi) it is $Bx_a \wedge c = +34°$.

Digitized by Google

and at the time it was not possible to decide from which of these the specimens came. According to information supplied by Mr. Roberts, it can now be stated to be the Machacamarca[1] which is "a few leagues to the north of the town of Potosi, and in the 'cercado' of that town." I have, however, been unable to find any published mention of this place. The Machacamarca about half-way between the towns of Oruro and Poopó, in the department Oruro, is not a mineral territory; it is here that the Oruro ores are amalgamated. A third Machacamarca, south-west of Palca, in the department Cochabamba, is given in the descriptions of the French Expeditions to South America of d'Orbigny (1826-1833) and Castelnau (1843-1847).

Mr. Roberts has been in correspondence with a mining friend of his at the Potosi Machacamarca, and has been able to send me a specimen from this place. In the quartzose matrix, the crystals of bournonite, bright octahedra of pyrites, and zinckenite (?), this specimen exactly resembles those previously examined; but it was only after searching at various times during a period of twelve months that a small crystal of augelite was at last found. This crystal, which is about 1 mm. in length, differs from those previously described in being more decidedly prismatic in habit, being elongated in the direction of the vertical axis. The forms present are $m\{110\}$ and $c\{001\}$, with narrow, indistinct $a\{100\}$ and negative pyramids $\{hhl\}$.

These occurrences of aluminium phosphate in the mineral veins of Bolivia are of interest in connection with the presence of cassiterite, but usual absence of apatite, as described by Stelzner.[2] It may perhaps be suggested that some of the occurrences of barytes mentioned by Stelzner (*loc. cit.* 1897, p. 111) may really be of augelite, though of course not all. I have myself, in the hopes of finding augelite, made optical and goniometric measurements of *barytes* from:—

(1). Mina Guernica at San Vicente (prov. Sud-Chichas, dept. Potosi), with bright crystals of tetrahedrite; also from San Vicente with cubo-octahedra of galena.

(2). Aullagas (prov. Chayanta, dept. Potosi), with pyrargyrite and stanniferous argyrodite (this vol. p. 6).

(3). Pulacayo mine, near Huanchaca (prov. Porco, dept. Potosi), with blende.

---

[1] This is about 200 kilometers N.N.E. of the new locality now described for augelite.

[2] *Zeits. deutsch. geol. Ges.* 1892, XLIV, 531; 1897, XLIX, 51; see *Min. Mag.* X, 261, and this vol. pp. 46, 7.

Digitized by Google

Stanniferous Argyrodite from Bolivia: The Identity of the so-called "Crystallised Bronguiardite" with Argyrodite-Canfieldite.

By G. T. Prior, M.A., F.G.S., and L. J. Spencer, M.A., F.G.S., Assistants in the Mineral Department of the British Museum.

[Read February 1st, 1898.]

THE occurrence in Bolivia of minerals containing the rare element germanium has been recently noted by Prof. S. L. Penfield. One of these minerals from Potosi, described by him in 1893,[1] has the chemical composition of the Freiberg argyrodite (the original source of germanium), but was determined to be cubic, and not monosymmetric, the system to which argyrodite was originally referred. To the supposed new mineral the name canfieldite was given, but when Weisbach's re-examination showed that the Freiberg argyrodite was possibly cubic, the name was transferred by Penfield to another mineral containing germanium, which he described in 1894.[2] This new mineral, Canfieldite, which came from La Paz, occurs as octahedra modified by dodecahedral planes, and is almost identical with argyrodite in all its physical properties, but differs from it chemically in that it contains tin isomorphously replacing germanium. The formula of argyrodite, as modified by Penfield's analyses of both the Bolivian and the Freiberg mineral, is $4Ag_2S.GeS_2$; that of canfieldite proper is $4Ag_2S.SnS_2$. The material actually analysed by Penfield was an isomorphous mixture of the two, containing about 7 per cent. of tin and nearly 2 per cent. of germanium. To such isomorphous mixtures he proposes that the name argyrodite or canfieldite should be given according as the germanium or the tin molecule predominates.

---

[1] "Canfieldite, a new Germanium mineral, and on the Chemical Composition of Argyrodite." *Amer. Journ. Sci.*, 1893, XLVI, 107–113; Abstract, *Min. Mag.* X, 336.

[2] "On Argyrodite and a new Sulpho-tannate of Silver from Bolivia." *Amer. Journ. Sci.* 1894, XLVII, 451–4; Abstract, *Min. Mag.* XI, 40. Under this title Penfield's two papers are united in *Zeits. Kryst. Min.* 1894, XXIII, 240–8.

Digitized by Google

The material now to be described is interesting crystallographically on account of the twinning, and chemically in giving a different ratio of tin and germanium from that found in the original canfieldite. It is also found to be identical with the cubic crystals which Damour, in 1854, referred to brongniardite, a massive sulph-antimonite of silver and lead which he had previously described.

Stanniferous Argyrodite from Aullagas, Bolivia.

In 1894 Mr. Jacobo Aillon presented to the British Museum two specimens as examples of red silver from the mines of the Colquechaca Company at Aullagas,[1] a mining village, 15,500 feet above sea level, in the province Chayanta, of the department Potosi.

The specimens consist mainly of a cavernous mass of pyrargyrite, showing on the free surfaces short prismatic crystals which are generally rounded and indistinct, but sometimes exhibit the forms $a\{10\bar{1}\}$ and $e\{110\}$. Intermixed with the pyrargyrite is some massive brown blende, one or two thin plates of barytes, a few specks of iron pyrites, and a little grey powdery kaolin, while on one of the specimens there is a considerable quantity of stephanite, both massive and in bright crystals.[2]

The main interest of the specimens, however, is derived from the fact that encrusting the pyrargyrite, as a later growth, are numerous small dull black cubic crystals, which on analysis were found to be stanniferous argyrodite.

Crystallographic Characters.—The crystals are very symmetrical and regular, and for the most part are isolated and almost completely developed on all sides, though occasionally several are grouped together. Many of them, however, especially those of type (2) described below,

---

[1] Aullagas is close to the town of Colquechaca, and lies east of the great lake Aullagas (or Poopó) and north of the town of Potosi. The mines here are noted for their very rich ore, consisting mainly of red silver and native silver. They have been described by H. Reck, *Petermann's geograph. Mitth.* 1867, 247; R. Peele, Junr. "The Silver Mines of Colquechaca, Bolivia," *Engineering and Mining Journal*, New York, 1894, LVII, 78, 100 (abstract, *Zeits. prakt. Geol.* 1894, 215); A. W. Stelzner, *Zeits. deutsch. geol. Ges.* 1897, XLIX, 89.

[2] On the crystals of stephanite the following forms were observed (the letters and indices are as given by Dana, *System of Mineralogy*, 6th edition, 1892):—

(i.) $c\{001\}$, $b\{010\}$, $m\{110\}$, $\pi\{130\}$, $q\{114\}$, $M\{1\bar{1}3\}$, $P\{\bar{1}11\}$.
(ii.) c, b, $t\{023\}$, $k\{011\}$, $d\{021\}$, q, M, $h\{112\}$, P.
(iii.) c, b, m, t, k, M, P. All these crystals are twinned on $m(11^{\bar{0}})$.

Partial measurements of minute crystals implanted on an octahedron of the stanniferous argyrodite gave—

(iv.) c, b, $s\{012\}$, t, d, etc.
(v.) c, b, t, d, $\delta_1\{071\}$, etc.

Digitized by Google

are only shells of material implanted upon a nucleus of pyrargyrite, specks of which mineral they also sometimes enclose. These shells are easily detachable, and their inner surfaces show impressions of other crystals, and are sometimes encrusted with minute crystals of iron pyrites, and with extremely minute acicular crystals of an undetermined black metallic mineral. The habit of the crystals varies considerably. The following types can be distinguished :—

Fig. 1.

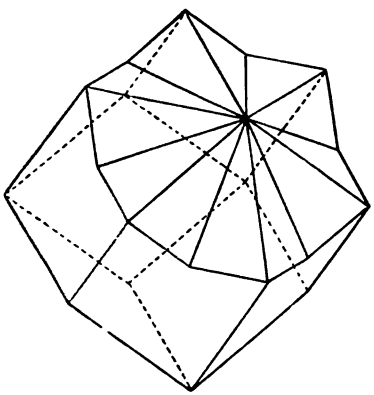
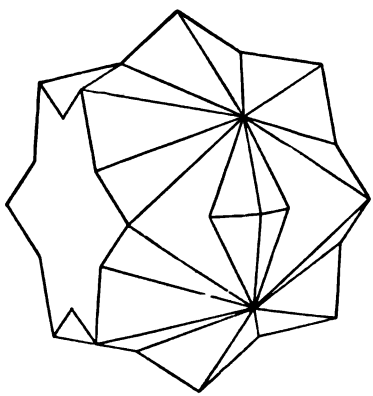


Fig. 2.



(1). *Simple* (i.e. *not twinned*) *octahedral crystals*, $o\{111\}$, *usually with narrow dodecahedral planes*, $d\{110\}$.

(*a*) Small, bright, and smooth crystals, with the dodecahedral planes very narrow or absent. These crystals, which do not exceed 0·5 mm. in diameter, occur only on the blende. On one crystal was measured $oo' = 70°25', 70°42'$; $od = 35°$ approx.

(*b*) Larger crystals, with dull, rough and pitted surfaces; dodecahedral planes are always present, and are occasionally more largely developed than the octahedral planes. These crystals average 1·5 mm. in diameter; the largest measures 5 mm. along the octahedral edge.

(2). *Dodecahedral crystals*, $d\{110\}$, *always twinned and never with octahedral planes.*

In size and surface characters these resemble type (1)*b*. The twin axis is perpendicular to $o\{111\}$. The following varieties can be distinguished, all of which occur with geometrical regularity :—

(*a*) Contact twins, showing no trace of the plane of junction. This twin occurs on gold, and is figured in most treatises on crystallography.

Digitized by Google

(*b*) Interpenetrating dodecahedra, with the two interpenetrating individuals at one end only of the twin axis, and at the other a simple crystal (fig. 1). Similar twins have been described by Sadebeck for blende.[1] The argyrodite "trilling" figured[2] by Weisbach is explained by these interpenetrating dodecahedra.

(*c*) Two interpenetrating dodecahedra, with re-entrant angles at both ends of the twin axis, as occur in sodalite.[3]

(*d*) Three interpenetrating dodecahedra, with two of the individuals twinned on two octahedral planes of the third individual (fig. 2). Here one pair of parallel planes is common to the three crystals, and four pairs are common to two crystals. A similar trilling, but far less regular, has been described by Sadebeck as occurring on blende.[4]

(*e*) Apparently simple dodecahedra, but on closer inspection showing numerous small projections on the faces due to small crystals in twin position.

(3). *An octahedron twinned according to the spinel law.*

Only one small indistinct crystal of this type was observed, this being on the specimen with the stephanite; all the other crystals on this specimen were of type (1)*b*. The re-entrant angle was measured as 37°—38½° (calculated 38°56′). This crystal was not examined chemically.

The difference between types (1) and (2) is very striking, and when considered in connection with the fact that twinning is mentioned in the two previous descriptions of argyrodite (from Freiberg and Bolivia), whilst Penfield's crystals of canfieldite were apparently simple, it would suggest that there is a difference in chemical composition. A separation of the two types for quantitative analysis was scarcely practicable, but as mentioned below (p. 10), both tin and germanium were found in the twinned as well as in the untwinned crystals, while the colour, fracture and streak were the same for all.

The very imperfect crystals of the Freiberg argyrodite, after being described originally as monosymmetric and later as orthorhombic, have, in consequence of Penfield's observations, been recently given as cubic

---

[1] *Zeits. deutsch. geol. Ges.* 1869, XXI, pp. 634, 636; figs. 10, 11, Plate XVII.

[2] This figure is repr duced in Dana's *System of Mineralogy*, 6th edition, 1892, p. 150, fig. 2.

[3] C. F. Naumann, *Lehrb. d. Kryst.* 1830, II, p. 232, fig. 621. This figure is given in Dana's *System*, p. 429.

[4] *loc. cit.* p. 634, fig. 19.

Digitized by Google

and tetrahedral.[1] In the crystals at present described there is, however, nothing that suggests hemihedral development.

Physical Characters.—The mineral is opaque and of a dull iron-black colour. Crystals, when bright, as in the first habit (1)*a*, have a metallic lustre with a very faintly perceptible purplish tinge on the natural faces The streak is black and shining.[2] The fracture is even, with a finely granular appearance and a dull metallic lustre. The hardness is between that of gypsum and calcite. The mineral is somewhat brittle, but not extremely so. The specific gravity (weight of 1 cc.) is 6·19 at 18°C. as determined on 1·1021 gram of the material collected for analysis.

Chemical Characters.—In collecting material for analysis much care had to be exercised owing to the intimate association of the mineral with pyrargyrite. Each crystal was broken open and examined in bright sunlight under the lens, and also under the microscope. By the indications of streak and the character and colour of the fractured surfaces, pyrargyrite could be easily detected, and was then scraped away, whilst fragments which had a gritty feel under the knife, owing to the presence of pyrites, were rejected. The material so collected consisted of crystals of types (1)*b* and (2), with perhaps more of the latter. It was all taken off the specimen, on which no stephanite was found, since, in colour and streak, this mineral might have been confused with that which we were examining.

Heated in the closed tube, the mineral gives a sublimate of sulphur, and on intense ignition before the blowpipe, a pale lemon-yellow transparent gummy-looking sublimate of germanium oxide. When heated on charcoal before the blowpipe, a silver bead is left, and a white sublimate tinged with yellow is formed far out on the charcoal, while nearer the assay minute transparent fused globules of germanium oxide may be detected under the microscope.

Apart from these blowpipe tests, however, the identity of the mineral with stanniferous argyrodite was indicated by the following method of qualitative analysis:—

Two or three of the small crystals were introduced into a piece of hard glass tubing drawn out at one end and connected at the other with a hydrogen apparatus. On heating to redness in a slow current of the gas, the mineral yielded on both sides of the assay a deep reddish brown

---

[1] A. Weisbach, *Neues Jahrb. für Min.* 1894, I, 98.

[2] The shining streak is obtained when a fragment of the mineral is crushed with a knife point on biscuit porcelain or on hard smooth paper; when the mineral is crushed on soft paper of loose texture, the streak is dull black, with a sooty appearance.

Digitized by Google

and black sublimate of germanium sub-sulphide and metallic germanium. The sublimate was dissolved in nitric acid, the solution evaporated to dryness, and the residue treated with a little ammonia into which sulphuretted hydrogen was conducted until it just dissolved. In this solution, on addition of a large excess of sulphuric acid and saturation with sulphuretted hydrogen, a bulky pure white precipitate of germanium bisulphide was produced. The residue in the combustion tube after the ignition in hydrogen was treated with nitric acid, and the tin separated from the silver as metastannic acid. This was dissolved in ammonium sulphide, and the tin precipitated as yellow sulphide on addition of acid. From the sulphide, spangles of metallic tin were obtained by reduction on charcoal before the blowpipe. In the filtrate from the metastannic acid, the silver was precipitated by hydrochloric acid. When examined by the above method, crystals of the two principal types, the twinned and the untwinned (see p. 8), were found to behave in a similar way, and to show the presence of both tin and germanium. In the case of the twinned crystals, 36 milligrams of material yielded about a milligram of oxide of tin, corresponding to about 2 per cent. of tin in the mineral.

In the quantitative analysis a similar method to that described by Penfield was adopted. The mineral was decomposed by prolonged digestion with fuming nitric acid, the liquid evaporated nearly to dryness, and the residue treated with hot water. The insoluble metastannic acid (containing also some germanium, silver and iron) was collected on a filter, and treated with ammonia, into which sulphuretted hydrogen was passed until the sulphides of tin and germanium passed into solution, leaving behind a little sulphide of silver and iron. The tin was then precipitated as sulphide by neutralising with sulphuric acid, and weighed as oxide, while the germanium in the filtrate was estimated as oxide on evaporating to dryness and treating the residue with nitric acid. After weighing, the oxide of tin was tested for germanium by reducing in hydrogen, and as a slight sublimate of germanium was obtained, the tin was estimated as metal.

In the original filtrate from the metastannic acid the silver was precipitated by hydrochloric acid, and the sulphur with barium nitrate. Before evaporating the filtrate, in order to avoid loss of germanium owing to the volatility of the chloride, the excess of hydrochloric acid was removed by means of silver nitrate; and at the same time the excess of barium was precipitated by sulphuric acid. The excess of silver was then removed by means of ammonium thiocyanate, and the filtrate evaporated to dryness. The residue was treated with ammonia into which

Digitized by Google

sulphuretted hydrogen was passed. The solution, containing germanium sulphide, was then filtered from the sulphide of iron, and evaporated to dryness. The residue was oxidised with nitric acid, and the germanium determined as oxide.

In a re-determination of the silver, made on 0·8197 gram from the same sample of powdered material, the mineral was decomposed by ignition in hydrogen, and the silver and tin in the metallic residue separated by means of nitric acid.

The result of the analysis made on 0·7608 gram is as follows (G. T. P.):—

			Atomic Ratios.		Calculated for $5(4Ag_2S.GeS_2)+2(4Ag_2S.SnS_2)$.
Ag	74·20	Mean of 73·89, 74·51	·6928	or 8	75·65
Ge	4·99		·0694	1·13	4·59
Sn	3·36		·0284		2·89
S	16·45		·5168	5·97	16·87
Fe	0·68				
Sb	traces				
	99·68				100·00

The so-called "Crystallised Brongniardite."

Under the name brongniardite, A. Damour in 1849[1] described a mineral from Potosi, Bolivia,[2] having the composition $PbS.Ag_2S.Sb_2S_3$ as determined by these analyses. On this original material no crystals occurred, but Damour considered that the mineral from its chemical composition should be isomorphous with the Binnenthal dufrenoysite ($2PbS.As_2S_3$) which he had recently investigated. At that time, however, having been misled by the association of cubic crystals of binnite with the mineral he had analysed, he was under the impression that dufrenoysite was cubic: he therefore suggested that should crystals of brongniardite be found, they would probably also be cubic. Accordingly when, a few years later, he[3] obtained from Louis Sæmann, a mineral dealer in

[1] "Notice sur la Brongniardite, nouvelle espèce minérale." *Annales des Mines*, 1849, [iv], XVI, 227–231; and F. de Castelnau, *Expédition dans les parties centrales de l'Amérique du Sud*, 1851, Vol. V, p. 440.

[2] Not Mexico, as at first stated, and as quoted in the text-books.

[3] "Note sur la cristallisation de la brongniardite, espèce minérale." *Annales des Mines*, 1854, [V], VI, 146–7.

Digitized by Google

Paris, a specimen, also from Bolivia, of apparently the same massive mineral, in the cavities of which however were small octahedral crystals, he appears to have been somewhat too readily convinced, as the result of a blowpipe examination,[1] that the crystals contained the same elements as the massive material, and that both were identical with the brongniardite he had previously described. The crystals were determined to be octahedra symmetrically truncated on all the edges, and to be consequently cubic. Brongniardite is therefore described in the text-books as a cubic mineral having the composition $PbS.Ag_2S.Sb_2S_3$.

In the British Museum a specimen of "massive and crystallised brongniardite," which was acquired with the Allan-Greg collection in 1859, is accompanied by Sæmann's label giving the locality as Aullagas, Bolivia, and mentioning the results obtained by Damour in 1854. This specimen in external characters agrees precisely with the published description of Damour. Thus it shows small octahedral crystals, with narrow dodecahedral planes, in cavities in a massive mineral; and pyrargyrite and blende, which are mentioned by Damour, are also present in small amount.

The massive material consists for the most part of a mineral (presumably brongniardite) which was found to contain silver, lead, antimony and sulphur, and to have a specific gravity of 5·99. Intimately associated with this mineral is some galena, and in parts also miargyrite, which occurs both massive and as indistinct crystals. It is on the latter mineral that the octahedral crystals occur.

Now these dull black octahedra have exactly the appearance of the type (1)*b* of stanniferous argyrodite described in the preceding section (p. 7); the streak, too, and the even fracture, with its granular appearance and dull metallic lustre, are very similar. So striking, in fact, was the resemblance of the crystals, that the specimens presented by Mr. Aillon were at first regarded as brongniardite. Therefore, when the small black crystals on the latter had been shown to be a stanniferous argyrodite, it became necessary also to make a chemical examination of the so-called brongniardite crystals.

For this purpose the amount of material available was very limited. Two or three of the crystals, weighing altogether 23·2 milligrams, were heated in hydrogen and examined in the way described on p. 9. The reddish brown sublimate formed on the combustion tube was dissolved,

[1] He noted, however, that the yellow sublimate on charcoal obtained from the crystals was less marked than that furnished by the massive mineral.

Digitized by Google

and finally yielded a pure white bulky precipitate of germanium sulphide, while in the metallic residue the presence of tin was proved by the production of the yellow sulphide,[1] and that of silver by precipitation as chloride. The weight of the silver chloride amounted to 22·1 milligrams, corresponding to about 72 per cent. of silver in the mineral. No lead or antimony was detected. Thus the result of the above physical and chemical examination is to prove that the crystals which were referred by Damour to brongniardite are really identical with a stanniferous argyrodite.

Through the kindness of Prof. A. Lacroix we have been able to examine fragments from several of the specimens of brongniardite collected by the Castelnau Expedition (1843-7), and now preserved in the Natural History Museum at Paris. One of these (labelled Potosi) shows the small octahedra of argyrodite-canfieldite, and in every detail resembles in appearance the specimen described in this section.

As far as we are aware, the only other mention that has been made of crystallised brongniardite is by L. F. Navarro.[2] A specimen from the Cueva de Plata, Sierra Nevada, now in the Natural History Museum at Madrid, is described as showing cubes resembling argentite in appearance. Further examination would probably prove them to be that mineral.

Occurrence of Sulphostannates in Bolivia.

The occurrence at Aullagas of stanniferous argyrodite is of interest as illustrating the wide distribution of sulphostannates in Bolivia. Canfieldite is found at La Paz, stannite[3] at Guanuni and Potosi, franckeite[4] (a sulphostannate and sulph-antimonite of lead) at Chocaya and Aullagas, kylindrite[5] (another sulphostannate and sulph-antimonite of lead) at Poopó, while the somewhat unsatisfactory plumbostannite[6] of Raimondi (which may possibly be identical with franckeite or kylindrite) occurs at Moho, Peru, only a few miles from the Bolivian boundary. Thus

---

[1] The precipitate was only a slight one, indicating that the mineral was in composition nearer to argyrodite than to canfieldite.

[2] *Anales Soc. Espanola Hist. Nat.* 1895, XXIV, Actas, p. 94.

[3] See Abstract, this vol. p. 46.

[4] A. W. Stelzner, *Neues Jahrb. Min.* 1893 II, p. 114; *Zeits. deutsch. geol. Ges.* 1897, XLIX, p. 141.

[5] A. Frenzel, *Neues Jahrb. Min.* 1893, II, p. 125.

[6] Also mentioned from Trinacria, near Poopó (*Zeits. deutsch. geol. Ges.* 1897, XLIX p. 693); and from Arangaro in Chili (*Bull. Soc. Fran. Min.*, 1895, XVIII, p. 340).

Digitized by Google

all the five naturally occurring sulphostannates at present known occur within or close to the borders of Bolivia, and, with the exception of stannite, are all peculiar to that region.

As recently emphasised by Stelzner,[1] the mode of occurrence of tin ores in Bolivia is of an exceptional character. Instead of occurring, as is almost invariably the case, in connection with deep-seated granitic rocks and in association with tourmaline, topaz, and other minerals containing boron and fluorine, usually considered as products of fumarole action, the tin ores of Bolivia are found accompanied by metallic sulphides[2] in the ordinary type of mineral veins, and in association with trachytic and andesitic rocks. It is just under such conditions that sulphostannates would be likely to be found.

---

[1] *Zeits. deutsch. geol. Ges.* 1892, XLIV, p. 531; 1897, XLIX, pp. 51–142; Abstr. *Min. Mag.* X, 261.

[2] A case of the occurrence together of cassiterite and andorite is noted by us in the last number of this Magazine (Vol. XI, p 299).

Digitized by Google

Atacamite from Sierra Gorda, Chili.

By G. F. Herbert Smith, B.A.,

Assistant in the Mineral Department of the British Museum.

[Read February 1st, 1898.]

In this paper are recorded the observations made upon four exceptionally good specimens of atacamite in the British Museum, which have been submitted to careful study with the object of determining the geometrical and physical characters of the mineral with greater accuracy than has hitherto been possible. The axial ratios have been calculated with the utmost refinement, an attempt has been made to determine the crystallographic symmetry by a study of the etched figures, and the values of the principal indices of refraction have for the first time been obtained.

The crystals are peculiar in habit, owing to the striking development of the pyramid forms. It may be mentioned that crystals of atacamite usually present a combination of the forms $b(010)$,[1] $m(110)$ and $e(011)$, and occur as long prisms whose edges are perpendicular to (001). Sometimes only one corner, in which m and e meet, is visible, in which case, since $mm''' = 67°$ and $ee' = 74°$ approximately, they resemble regular octahedra. In the case of the four specimens under consideration, the summit of the crystals is altogether altered in appearance; the dome form e still occurs, though often very small, but the pyramid faces, instead of being, as before, almost entirely absent, or at any rate barely visible, now form the most striking feature.

The four specimens may be taken as two pairs, the individuals of each being identical in all respects except that of size. The two specimens of one pair are from Sierra Gorda, in the northern part of the Desert of Atacama; the other two are *probably* also from the same region.

---

[1] The same letters are used for the faces as in Dana's *System of Mineralogy*, 6th edition.

Digitized by Google

1. *The axial ratios.*

The axial ratios given in Dana's *System of Mineralogy*, sixth edition, were calculated by Zepharovich from measurements made by himself and Klein on crystals from South Australia. There are in the British Museum numerous specimens from the Wallaroo mines. The crystals on these are good, but even the best cannot be compared with those from Sierra Gorda [1] Some pains, therefore, were taken to obtain accurate values of the ratios. The faces of the form $m(110)$ unfortunately give as a rule so many images, with so much overlapping, that accuracy was out of the question, and, as will be seen later, considerable variations were obtained in the value of the prism angle. The angles best available for measurement were found to be $rr''(111 : \bar{1}\bar{1}1)$, $rr'''(111 : 1\bar{1}1)$, $rr'(111 : \bar{1}11)$ and nr (121 : 111). Only faces which gave perfectly definite images were employed; for this reason only the angle nr can be derived from the form n, the faces being often too small to give a sufficiently bright image. The goniometer used was a large Fuess instrument reading to 10 seconds, and by estimation to seconds. Only three crystals were thus measured. None of the others observed attained to the same degree of excellence, and would, if used, have only compromised the real accuracy of the results. After properly weighting the means of the four angles mentioned above, the axial ratios were calculated by the method of least squares. The result is as follows:—

$$a : b : c = 0{\cdot}66130 : 1 : 0{\cdot}75293.$$

For comparison, a list of axial ratios obtained by other observers is added:—

$a : b : c = 0{\cdot}66126 : 1 : 0{\cdot}75149$	Zepharovich and Klein[2]
$0{\cdot}66129 : 1 : 0{\cdot}75453$	Des Cloizeaux[3]
$0{\cdot}6613 : 1 : 0{\cdot}7501$	Lévy[4]
$0{\cdot}6703 : 1 : 0{\cdot}7581$	Miller
$0{\cdot}66186 : 1 : 0{\cdot}75302$	Brögger[5]
$0{\cdot}6683 : 1 : 0{\cdot}7506$	Zepharovich[6]

[1] Genth seems to have analysed similar crystals (see *Amer. Journ. Sci.* 1890, XL, 207), but no mention is made of any crystallographic or optical examination.

[2] *Ber. Akad. Wien*, 1873, 68(1), 120.

[3] *Nouvelles Recherches.*

[4] *Description d'une Collection de minéraux.*

[5] *Zeits. Kryst. Min.* 1879, III, 489.

[6] *Ber. Akad. Wien*, 1871, 63(1), 6.

Digitized by Google

Table I. gives the angles as calculated from the axial ratios and as observed :—

TABLE I.

Angle.	Calculated.	Observed Mean.	Diff.	Limits.	Edges.
111 : $\bar{1}\bar{1}1$ *rr''*	107°32'50"	107°32'21"	+29"	107°31'21"– 107°33'44"	5
111 : $1\bar{1}1$ *rr''*	52 50 34	52 51 7	—33	52 50 24 — 52 52 0	4
111 : $\bar{1}11$ *rr'*	84 34 40	84 34 32	+ 8	84 34 28 — 84 34 40	4
111 : 121 *rn*	18 23 46	18 24 13	—27	18 23 19 — 18 24 52	7

The following are the calculated and observed values of *mm'''* on these crystals :—

Angle.	Calculated.	Observed Mean.	Limits.	Edges.
110 : $1\bar{1}0$ *mm'''*	66°57'12"	66°55'14'	66°41'40"—67°4'50"	5

2. *The face-indices and measurements.*

The general habit of the Sierra Gorda crystals is represented in fig. 1. *h* is a new and interesting form, whose faces are fairly large but invariably striated parallel to their intersections with *e*. As might, therefore, be expected, the observed values are not very accurate. This, however, will not account altogether for the very large variations noted; evidently vicinal faces are often present. The observed values fall more or less into groups, as given in Table II. It must be remarked that all these forms lie in the zone *me*. The simplest indices that can be assigned to *h* are (132), but the corresponding value is by no means the one most often met with, though it is the one observed when the face is least striated and the image most clear. On one crystal, indeed, two faces gave each two distinct images, which measurement showed corresponded to the forms (132) and (5·14·9), and could be plainly seen to be really double faces.

TABLE II.[1]

Angle.	Calculated.	Observed Mean.	Limits.	Edges.
110 : 253	41°42' 5"	42°41'	41°49'—42' 0'	5
110 : 5.14.9	45 10 32	45 16	44 33½—45 58½	12
110 : 132	47 5 13	47 22½	46 35 —47 30	5
110 : 4.13.9	49 7 26	40 57	49 47 —50 8	3
110 : 275	51 51 5	52 25	51 41 —53 10	4
$1\bar{1}0$: 132	95 16 7	95 8	93 51 —97 11	6

[1] In Table II. and the following tables the measurements were made on a smaller Fuess goniometer reading to half-minutes.

Digitized by Google

The following forms have been observed on these crystals:—

b(010) Only twice seen; probably then due to cleavage.

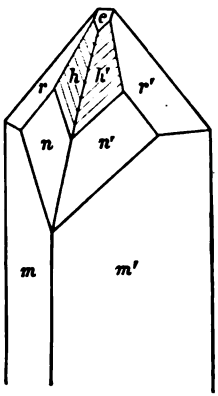
c(001) Infinitesimally small, no image given.

u(101) Seen twice only on one crystal, no image.

d(201) Very small, no image.

m(110) The principal prism form. As mentioned above, it gives multiple images.

Fig. 1.



s(120) Very small, no image.

e(011) Small, but images good.

r(111) Large faces: images beautifully distinct.

n(121) Faces not so large as in r, and often small: generally good images.

h(132), (5.14.9); see above.

The crystals used are from 3-5 mm. in length, but numerous smaller crystals are also present.

In Table III. will be found the calculated and observed values of the principal angles measured.

TABLE III.

Angle.	Calculated.	Observed Mean.	Limits.	Edges.
110 : $1\bar{1}0$ mm'''	66°57′ 12″	66°57′ 17″	66°17′ — 67°46′	12
111 : $\bar{1}\bar{1}1$ r ''	107 32 50	107 38 46	107 22 —107 56	6
110 : 121 mn	33 33 20	33 31 32	33 14 — 33 52	11
110 : 011 me	70 37 22	70 37 14	70 26 — 70 52½	16
$1\bar{1}0$: 111 $m'''r$	71 35 26	71 34 0	71 1 — 71 54	14

Digitized by Google

Associated with Atacamite on the first pair of specimens, and often mixed with it, is another mineral, which on examination was found to be caracolite. It generally occurs as a crystalline crust adhering to the vein-stuff on which it lies, but a few crystals resembling hexagonal tablets were noticed. Caracolite from this region has already been described by Mr. Fletcher,[1] and observations made on the present material agree closely with his. Goniometrical measurements, taken alone, would suggest that this mineral belongs to the hexagonal system; but, on placing one of these tablets between crossed nicols in the position which should give a uniaxial figure, no such figure can be seen, nor is it possible by rotating the nicols to obtain any variation in the light transmitted through the crystal. If, however, a fragment be first crushed and then examined between crossed nicols, minute twin-crystals may be seen, as has been remarked by Professor Websky,[2] who, therefore, concluded that the crystals are really orthorhombic, and imitate hexagonality by twinning about a prism face after the manner of aragonite. Indeed, some of the prism faces on these hexagonal tablets are distinctly double faces, and give two images about 40′ apart; and hence caracolite is probably orthorhombic with the angle $(110 : 1\bar{1}0)$ approximately 60°26′.

A qualitative analysis of the crust showed the presence of lead, sodium, chlorine and sulphur, which is in accordance with the formula determined by Professor Websky.

The other two specimens are also of considerable interest. In the case of each, innumerable crystals of atacamite spring from a matrix of the same mineral, and are covered with a reddish iron oxide. They have evidently been exposed to the air, and are (except in cavities) much weather-worn.

Curiously enough, in nearly the same position as on the Sierra Gorda crystals there is a new and peculiar form θ (fig. 2). It lies in the zone bs, whereas h is in the zone bm. Although the faces of this form are so large, only on two small crystals from a small cavity were they found sufficiently smooth to give images. Even when the other large faces gave good reflections, all that could be seen from the θ faces was a vague, dim blurr extending over some ten degrees. On the two crystals it was possible to measure five faces. They usually gave three images, whose relative positions varied with each face, and were never quite in the zone bs as they should be if the indices (273)—the simplest satis-

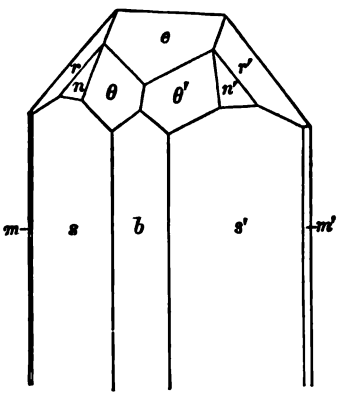
[1] *Min. Mag.* 1889, VIII, 172.

[2] *Ber. Ak. Berlin*, 1886, p. 1,045.

Digitized by Google

fying the conditions—are correct. There are probably three low vicinal pyramids on each face of θ. This form has apparently been noticed by Brögger[1] on a crystal from Chili. He suggested {142} as the probable symbol, but could obtain no measurements.

Fig. 2.



Besides θ there are four other new forms, namely, $\phi\tau\rho\sigma$; $\phi(131)$ has small faces giving single images, this form was only seen on the two crystals already mentioned; $\tau(890)$ or $(9{\cdot}10{\cdot}0)$, indices doubtful, presents itself as a minute face between m and t; and finally, on one crystal two faces $\rho(443)$, $\sigma(332)$ were seen in the zone mr. The angles determining the various forms are given in the following table:—

TABLE IV.

Angle.	Calculated.	Observed Mean.	Limits.	Edges.
120 : 273 $s\theta$	30°34′ 24″	30° 5′	29°33′—30°48′	5
010 : 273 $b\theta$	35 32 37	34 56		1
120 : 131 $s\phi$	23 47 14	23 33½		1
010 : 131 $b\phi$	33 51 23	33 38	33°25′, 33°35′, 33°54′	3
110 : 890 mr	3 10 16	3 3	2°21′— 3°53′	10
110 : 443 $m\rho$	28 47 20	28 19	27°40′, 28°58′	2
110 : 332 $m\sigma$	26 2 0	25 30	24°36′, 25°40′, 26°15′	3

The other forms observed are:—

$b(010)$ Large; surface is rough, but gives good image.

$a(100)$ Very small, seldom seen.

$c(001)$ Very small, and always rounded.

[1] *Zeits. Kryst. Min.* 1879, III, 489.

Digitized by Google

x(140) Very small, but images fairly good.
k(130) Very small, diffused image.
s(120) Large; surface rough, but gives good image.
l(230) Very small, not often found, dim image.
t(560) Very small, not often found, dim image.
m(110) Small, but image distinct.
r(111) Very good face.
n(121) Not so large as r, but gives distinct image.
e(011) Large, and gives good image.
u(101) Very small, no image, only seen twice.

The crystals occur from 2-6 mm. in length.

The calculated and observed values of the principal angles are given in the following table:—

TABLE V.

Angle.	Calculated.	Observed Mean.	Limits.	Edges.
110 : 1$\bar{1}$0 *mm‴*	66°57′ 12″	67° 6′ 42″	65°57′ — 67°40′	23
120 : $\bar{1}$20 *ss′*	74 11 14	74 20 34	74 0 — 74 57	23
011 ; 0$\bar{1}$1 *ee′*	73 57 16	73 56 0	73 40 — 74 10	6
111 : $\bar{1}\bar{1}$1 *rr″*	107 32 50	107 33 50	107 32 —107 36	6
111 : $\bar{1}$11 *rr′*	84 34 40	84 34 0	84 32 — 84 36	6
111 : $\bar{1}$11 *rr‴*	52 50 34	52 51 50	52 38 — 53 5	5
120 : 011 *se*	61 19 42	61 23 9	61 9 — 61 39	27
120 : 111 *sr*	40 28 18	40 22 38	40 2 — 40 38½	22

The following forms noted by other observers have not been found on these crystals:—

δ(023), i(0.10.9), o(021), g(031), q(221), z(331), w(992), f(211), y(321), and v(762).

3. *The etched figures.*

Crystals of atacamite, though sometimes figured as if completely developed, are rarely doubly terminated. In the British Museum there is one large crystal, about 4 cm. in length, from the Wallaroo mines, which shows one face of the form e at the other end. Also the few Sierra Gorda crystals, which have grown on their side, give with the goniometer faint indications of faces underneath. It is not, therefore, possible to determine by simple measurement whether the mineral is truly holohedral, and recourse must be had to some other method, such as etching.

Atacamite is readily dissolved by dilute acids. Hydrochloric, nitric and sulphuric acids were used, and all give the same results; the first

Digitized by Google

named is the least convenient, owing to the deposition of copper chloride crystals.

The form *m*, which occurs well developed on crystals belonging to the first pair of specimens, is quickly attacked by acids. Large cavities are formed, whose intersections with the face—sometimes a little curved—are isosceles triangles. The faces produced by etching are sufficiently smooth to give measurable images. The unequal side is a prism face, probably *k*; the two equal sides are faces in the zone *mu*, either (132) and (13$\bar{2}$) or (231) and (23$\bar{1}$). Measurements are obtained corresponding to both sets.

TABLE VI.

Angle.	Calculated.	Observed.
110 : 132	21°35′	20°10′, 20°22′, 20°15′
110 : 231	14 40½	14°4′, 15°42′
010 : 130 *bk*	29 47	28°40′

The figures appear to be quite symmetrical above and below, indicating the holohedral character of the crystals, but when the form *b* on crystals taken from the second pair of specimens is etched, the result is not quite in accordance with this view. On applying the acid, small vertical marks are seen, distinctly larger at the top than at the bottom. They grow in number, though not in size, till the face is covered with them, and finally the crystal splits up. This face is but slowly attacked by the acid.

The form *s* showed no figures at all.

As no trace of electric polarity was observed on heating the crystals, the balance of evidence is in favour of holohedral symmetry.

4. *The Optical Characters.*

The refractive indices for this mineral have hitherto not been determined. There is considerable difficulty in finding them, since they are too high for the total reflectometer, and the crystals are, if of any considerable size, only slightly transparent. It was found, therefore, impossible to get any result by employing the monochromatic light given by a volatilising salt; but, since the mineral absorbs all light but the green, measurable images for this light were obtained at minimum deviation with a Welsbach burner.

As none of the large prism forms have their internal angles small enough, faces unsymmetrical with regard to the principal planes had to be used, the labour of calculation being thereby considerably increased.

Digitized by Google

Since there is an excellent cleavage parallel to b, a prism consisting of the refracting faces bm on the first pair of specimens could be utilised, whilst the second pair gave the prisms bs and be.

The section of the wave-surface by a principal plane is a circle and an ellipse. The image corresponding to the former involves only one index, but the other involves two.

Consider the section parallel to the plane (001)—

$$\left.\begin{aligned} x^2+y^2 &= c^2 \\ a^2x^2+b^2y^2 &= a^2b^2 \end{aligned}\right\}$$

From the first equation we obtain the ordinary formula—

$$\frac{1}{c}=\gamma=\sin\tfrac{1}{2}(\mathrm{A}+\mathrm{D})/\sin\tfrac{1}{2}\mathrm{A},$$

And from the second—

$$\frac{1}{C^2S^2}-\tfrac{1}{2}\left(\frac{1}{C^2}+\frac{1}{S^2}\right)(a^2+b^2)+a^2b^2-\tfrac{1}{2}\left(\frac{1}{C^2}-\frac{1}{S^2}\right)\cos 2\phi\,(a^2b^2)=0.^1$$

Where $C=\cos\frac{1}{2}(\mathrm{A}+\mathrm{D})/\cos\frac{1}{2}\mathrm{A}$, $S=\sin\frac{1}{2}(\mathrm{A}+\mathrm{D})/\sin\frac{1}{2}\mathrm{A}$.

ϕ is the angle which the plane bisecting the prism angle makes with the plane of a ($a>b$); A is the angle of the prism, D the angle of deviation, $a=1/\alpha$, $b=1/\beta$, $c=1/\gamma$; $\alpha\beta\gamma$ are the three principal indices of refraction.

The three prisms already mentioned yield three pairs of equations to determine the three refractive indices.

Before giving these equations, there are two points worth noting:—Firstly, the two images can be easily distinguished by means of a nicol; for the image corresponding to the circle must be brightest when any reflected image is brightest, and *vice versâ:* just the contrary is the case with the other image. Secondly, in all three cases $2\phi=\mathrm{A}$, and therefore—

$$\frac{1}{C^2S^2}=\tfrac{1}{2}\left(\frac{1}{C^2}+\frac{1}{S^2}\right)-\tfrac{1}{2}\left(\frac{1}{C^2}-\frac{1}{S^2}\right)\cos 2\phi;$$

a convenient check on the arithmetical accuracy.

---

[1] G. G. Stokes, "On a formula for determining the optical constants of doubly refracting crystals," *Camb. and Dublin Math. Journ.* 1846, I. 183; *Math. and Phys. Papers, Cambridge*, 1880, I, 148; *Cf.* Liebisch, *Physikalische Krystallographie*, Leipzig, 1891, equation at bottom of page 393.

Digitized by Google

The six equations and the data for deriving them are—

Prism bm; circle $A = 56°31\frac{1}{2}'$ $D = 69°0'$

ellipse $D = 66°\ 9'$ $\quad \frac{1}{S^2} = \cdot2912$ $\quad \frac{1}{C^2} = 3\cdot3721$

$$\gamma = \frac{1}{c} = \frac{\sin 62°45\frac{3}{4}'}{\sin 28°15\frac{3}{4}'} = 1\cdot878 \qquad (1)$$

$$\cdot9820 - 1\cdot8316\ (b^2+a^2) + a^2b^2 = -\cdot8496\ (b^2-a^2) \qquad (2)$$

Prism bs; circle $A = 37°\ 5\frac{1}{2}'$ $D = 36°25'$

ellipse $D = 35°28'$ $\quad \frac{1}{S^2} = \cdot2890$ $\quad \frac{1}{C^2} = 1\cdot3832$

$$\gamma = \frac{1}{c} = \frac{\sin 36°45\frac{1}{4}'}{\sin 18°32\frac{1}{4}'} = 1\cdot882 \qquad (3)$$

$$\cdot3997 - \cdot8361\ (b^2+a^2) + a^2b^2 = -\cdot1364\ (b^2-a^2) \qquad (4)$$

Prism be; circle $A = 53°\ 1\frac{1}{2}'$ $D = 59°20'$

ellipse $D = 60°10'$ $\quad \frac{1}{S^2} = \cdot2860$ $\quad \frac{1}{C^2} = 2\cdot6428$

$$\alpha = \frac{1}{a} = \frac{\sin 56°10\frac{3}{4}'}{\sin 26°30\frac{3}{4}'} = 1\cdot861 \qquad (5)$$

$$\cdot7556 - 1\cdot4641\ (b^2+c^2) + b^2c^2 = -\cdot7085\ (b^2-c^2) \qquad (6)$$

Hence $\gamma = 1\cdot880$ $(\pm\cdot002)$.

This value is now substituted in (6) and β found—

$$b^2 = \cdot2983$$
$$\beta = 1\cdot831$$

From (2) and (4) after substituting for b we find a and α—

$$a^2 = \cdot2892 \text{ and } \cdot2879$$
$$\alpha = 1\cdot860 \quad ,, \quad 1\cdot863$$

Also direct from (5) $\alpha = 1\cdot861$

Therefore $\alpha = 1\cdot861$ $(\pm\cdot002)$.

The refractive indices are then for green light—

$$\alpha = 1\cdot861$$
$$\beta = 1\cdot831$$
$$\gamma = 1\cdot880$$

Whence it may be seen that the axial plane is parallel to (100), and that the axis perpendicular to (010) is the acute bisectrix.

Digitized by Google

The angle between the optic axes for thallium light was measured in cedar oil, whose refractive index for sodium light was found to be 1·5312. Values were obtained varying from 95° to 97°.

The real angle between the axes $= 2 \sin^{-1} \frac{\beta}{\alpha} \sqrt{\frac{\gamma^2 - \alpha^2}{\gamma^2 - \beta^2}}$

which becomes in the present case 74°56′.

Further, the angle in oil is found on calculation to be 96°50′.

Digitized by Google

On Sphærostilbite.

By G. T. Prior, M.A., F.G.S.,

Assistant in the Mineral Department of the British Museum.

[Read April 5th, 1898.]

SPHÆROSTILBITE was one of a number of sub-species which Beudant, in his *Mineralogy*, published in 1832, separated from ordinary stilbite owing to slight differences in chemical composition. In a typical specimen from the Faroe Islands he describes the sphærostilbite as implanted upon ordinary stilbite, in the form of small globules, presenting a fibrous radiated structure and brilliant pearly lustre on the fractured surface. Unlike stilbite, it gelatinised with acids, and it also had a specific gravity (2·31) slightly higher than that of stilbite. According to the analyses given by Beudant, however, it differed in chemical composition so little from ordinary stilbite that in later text-books (Glocker, 1839; Breithaupt, 1847, &c.) it has always been referred to that species.

In Greg and Lettsom's *Mineralogy* (1858, p. 163), sphærostilbite is described under stilbite, and there occurs the statement, referred to by Dana (*System of Mineralogy*, 6th edition, p. 584), that according to Dr. Heddle sphærostilbite is "merely stilbite in the form of minute primary crystals disposed upon delicate radiating tufts of mesolite, the presence of which determines the spherical form, causes the gelatinisation in acids, and accounts for the slight variation in composition." In the above statement, instead of *mesolite* it is almost certain from the description that Heddle really meant *mesole*, for it was in 1857 that he published in the *Philosophical Magazine* the analytical work by which he showed that the delicate needles of mesolite and the radiated spheres with pearly lustre of mesole (or, as he preferred to call it, faroelite) must be considered as distinct species. Long before this, mesole had been referred by Haidinger (*Best. Min.* 1845, 529) to thomsonite, and this was confirmed by the examination of the optical characters made by Des Cloizeaux. As the result probably of his observations on mesole, Des Cloizeaux (*Min.* 1862, 419) was led to express the opinion with regard to sphærostilbite

Digitized by Google

that "it appears to result, from Beudant's description, that the name sphærostilbite and that of mesole have been applied to the same mineral," and that originally there had probably been confusion between the specimen described and that which was analysed.

Some years ago I had occasion to examine a number of doubtful specimens of zeolites belonging to a collection made by Miss Caroline Birley in the Faroe Islands. Amongst these specimens were some which were provisionally named sphærostilbite, owing to their resemblance to specimens so labelled in the British Museum. In appearance these specimens answered closely to Heddle's description, quoted above, if mesole be substituted for mesolite. Thus they consist of a sort of open network of confusedly-grouped and imperfect crystals, presenting pearly cleavage surfaces and resembling stilbite, disposed upon ordinary compact mesole (faroelite), the presence of which determines the spherical form. In most cases, between the crystal network and the compact radiated spheres of mesole is interposed a material more compact and less definitely crystallised than the network, but less compact and more crystalline than the mesole.

In the determination of doubtful specimens in Miss Birley's collection, reliance was chiefly placed upon examination of the optical characters. Small fragments crushed in oil on a slide were examined under the microscope with a $\frac{1}{12}$-inch immersion objective. In the case of the so-called sphærostilbites it was found that material taken from the base (mesole), from the intermediate portion, or from the upper and more definitely crystallised network, all behaved in the same way, and presented the optical characters, not of stilbite, but of thomsonite. Thus almost all the cleavage flakes obtained by crushing a fragment compensated with the quartz wedge across the length of the flake, and in convergent light showed the emergence of a positive bisectrix with the plane of the optic axes at right angles to the length of the flake and an optic axial angle of about 80°, as measured with an eyepiece micrometer. Intermixed with such flakes were only very few of apparently a somewhat more strongly doubly refractive mineral which showed no definite optic figure, and compensated with the quartz wedge along the length of the flake. The latter flakes doubtless consist of stilbite, the presence of which would account for the slightly higher silica percentage of faroelite over that of normal thomsonite. On close examination the material forming the crystal network was seen to consist of sheaf-like bundles, which are very similar to those of stilbite, and present a similar pearly cleavage surface; but, unlike that mineral, they have

Digitized by Google

square terminations, and thus resemble the sheaf-like aggregates—of comptonite (thomsonite) from Vesuvius. On many of the specimens of faroelite in the British Museum the square terminations can be seen as markings on the surface of the spheres. All the specimens of so-called sphærostilbite in the British Museum were found to have, like the specimens collected by Miss Birley, the optical characters of thomsonite, and not those of stilbite.

To confirm this determination, a quantitative analysis was made on 0·5299 gram of the crystal network carefully separated from the more compact spheres of mesole.

The result of this analysis is given under I., and under II. are the numbers obtained in a partial analysis made on 0·3733 gram of material from another specimen; while, for the sake of comparison, under III. is given the result of an analysis by Lemberg of a faroelite from the Faroe Islands, and under IV. the result of an analysis by the same analyst of a stilbite from the Faroe Islands.

		I.	II.	III.	IV.
SiO_2	...	40·69	41·47	39·98	55·26
Al_2O_3	...	28·63	28·69	29·62	17·36
CaO	...	12·98		11·77	7·55
Na_2O	...	5·66		4·87	1·93
H_2O	...	12·42	12·63	13·76	18·62
		100·38		100·00	100·72

The result of the analysis showed that the specimens of so-called sphærostilbite, which had been proved to have the optical characters of thomsonite, had also the chemical composition of that mineral.

Of the museum specimens three belonged to the Allan-Greg collection acquired in 1859, another was presented in 1858 by P. Dudgeon, Esq., a great personal friend of the late Prof. Heddle, while the third was purchased in 1858 from Mr. Alex. Rose, of Edinburgh. It was, therefore, shown that material from different sources which had been regarded as sphærostilbite must be referred to thomsonite, and not to stilbite.

The result of the above examination, made some years ago, was not deemed of sufficient importance to publish. Since that time, however, the museum has from time to time acquired specimens, labelled sphærostilbite, from American and Australian localities (Oregon, Flanders Island, Tasmania, &c.), and these, like the Faroe specimens, have, on optical examination, always proved to consist of thomsonite, and not of

Digitized by Google

stilbite. It therefore appeared to be desirable to place on record the fact that in many cases the name sphærostilbite has been applied in the past, and is still being applied, to material consisting of thomsonite, and not of stilbite.

At the same time the fact remains that stilbite can, and in fact does occur in spherical radiating aggregates. In the British Museum collection, besides the well-known "puflerite" from Puflerloch, Seisser Alps, there are specimens of stilbite in the form of spheres showing radiated structure from the Faroe Islands; Goschenen Alps; Rezbanya, Hungary; Arendal, Norway, &c.; but in these cases the mineral shows the optical characters of stilbite, and like stilbite does not gelatinise with acids.

Conclusions.

1. In all probability no such mineral as that described by Beudant as sphærostilbite exists, viz. a mineral occurring in spherical aggregates with a specific gravity of 2·31, gelatinising with acids, and having approximately the chemical composition of stilbite.

2. In all probability Heddle's sphærostilbite, described as consisting of stilbite implanted upon mesolite, is identical with the material described above, which consists of thomsonite in sheaf-like aggregates implanted upon the more compact thomsonite in the form of spherical aggregates (mesole or faroelite).

3. To avoid confusion the name sphærostilbite should be discarded, for it cannot be justly applied to specimens of stilbite in spherical aggregates, since they do not gelatinise with acids.

Digitized by Google

On Senaite, a new Mineral belonging to the Ilmenite Group, from Brazil.

By Dr. E. Hussak, of the Geological Survey of S. Paulo; and

G. T. Prior, M.A., F.G.S., Assistant in the Mineral Department of the British Museum.

[Read April 5th, 1898.]

THIS new ilmenite-like mineral, containing lead and manganese, was found in rounded fragments and rough crystals in the diamond-bearing sands of Diamantina, Minas Geraes, Brazil (at Dattas, Rio Cipó, &c.).

Crystallographic and other physical characters (E. H.).

The crystal system is rhombohedral, tetartohedral (trigonal rhombohedral of Groth). The vertical axis $c=0{\cdot}997$.

The mineral is very rich in faces. The rhombohedral planes are very bright, while the basal plane, owing to twinning, is generally uneven and, like the prism faces, dull.

Twins are very common. They are so-called supplementary twins on $\infty R2(10\bar{1})$, such as have been described by F. Becke on dolomite. The basal planes of the two individuals fall in one plane, and the prism faces meet at an angle of 30°.

Some of the measured angles approximate to angles obtained by Lévy for mohsite.[1] Thus—

	Senaite (Hussak)		Mohsite (Lévy)
$c(0001) : S(\bar{2}021)$	$=66°38\frac{1}{2}'$	...	67°30′
,, $: r(10\bar{1}1)$	$=49\ 4$	...	50 21
,, $: z(40\bar{4}1)$	$=77\ 33\frac{1}{2}$	...	78 18

The mineral has no cleavage. The fracture is conchoidal, the hardness just above 6 (splinters scratch glass). The specific gravity is variable; that of the compact grains, apparently perfectly fresh and homogeneous,

[1] *Phil. Mag.* 1827, I, 221. In this paper no chemical characters are given, and it is only doubtfully that the mineral has been since referred to ilmenite.

Digitized by Google

used in the analysis, was 4·78 (G. T. P.), while that of decomposed crystals was as low as 4·22 (W. Florence), and that of undecomposed crystals with cavities as high as 5·301 (E. H.). The colour of the mineral is black, and the lustre sub-metallic. The colour of the powder is brownish black. In very thin splinters the mineral is transparent, with an oil-green to greenish-brown colour. It is weakly doubly refracting, non-pleochroic, and optically uniaxial. The mineral is not magnetic.

Some of the crystals are partially decomposed. In these cases the prism faces are covered with a brown coating of limonite, while the rhombohedral faces have a yellow earthy crust consisting of titanic acid, with only a trace of iron.

Chemical Characters (G. T. P.).

The mineral is infusible before the blowpipe, but after heating loses its lustre and shows signs of alteration, It is decomposed by hydrofluoric acid, by boiling sulphuric acid, and by fusion with hydrogen potassium sulphate. The material used in the quantitative analysis consisted of rounded fragments (not crystals) apparently quite fresh and homogeneous. The mineral was fused with hydrogen potassium sulphate. On treating with cold water and filtering, most of the lead was separated as sulphate, while the remainder in the filtrate was precipitated as sulphide by sulphuretted hydrogen. The titanic acid was thrown down by long-continued boiling, while carbonic acid was passed through the liquid. The iron was then precipitated by sodium acetate, and the manganese by ammonium sulphide.

The ferrous iron was determined by decomposing the mineral with hydrofluoric and sulphuric acids in an atmosphere of carbonic acid, and titrating with potassium permanganate.

The percentage of titanic acid was checked by a colorimetric determination which gave 56·85.

Under I. is given the result of the complete analysis made on 0·6382 gram, and under II. that of a preliminary analysis made on 0·3247 gram of a different sample.

Digitized by Google

	I.	Molecular ratios	II.	III.	IV.	V.
TiO_2	=57·21	·6962	56·11	59·20	63·31	69·51
PbO	=10·51	·0474	11·43			
FeO	= 4·14	·0562		4·90	35·99	28·67
Fe_2O_3	=20·22	·1267	25·16	32·11		
MnO	= 7·00	·0988	7·81	1·73		1·41
MgO	= 0·49	·0123			0·82	0·32
SnO_2	= 0·11	·0073		SiO_2 1·16	1·25	0·44
	99·68			99·10	101·37	100·45

The numbers lead to no very satisfactory formula. If all the iron be considered to be present as FeO, and the manganese as MnO_2 instead of MnO, we get approximately $(FePb)O.2(TiMn)O_2$; but in the present state of our knowledge of the composition of ilmenite, it would be rash to insist on such a formula. The amount of titanic acid is much too great for the ordinary ilmenite formula $FeO.TiO_2$ advocated by Penfield.[1]

For the sake of comparison, under III. is given the result of an analysis by Mackintosh[2] of an ilmenite from Brazil; and under IV. the result of an analysis by Peek[3] of a so-called ilmenite from Bedford Co., Virginia. In both of these analyses the amount of TiO_2 is too great for the ordinary formula of ilmenite. Under V. are given the numbers obtained in the analysis of Janovsky's iserite[4] which correspond to the formula $FeO.2TiO_2$.

The low specific gravity (4·78) of the material analysed with respect to that of the crystals (5·3) would suggest that it was altered. It gave, however, no loss on ignition, and showed no external signs of decomposition. A crystal fragment with specific gravity 5·08 showed on analysis the presence of iron, titanium, lead and manganese, and in appearance was precisely similar to the material quantitatively analysed.

The name senaite has been given to the mineral in honour of Prof. Joachim da Costa Sena, of Ouro Preto, Minas Geraes, Brazil, from whom the samples of sand containing the mineral were received.

---

[1] *Amer. Journ. Sci.* 1897, IV, 108.
[2] *Amer. Jour. Sci.* 1885, XXIX, 342.
[3] *Amer. Chem. Journ.* 1897, XIX, 232.
[4] *Ber. Akad. Wien.* 1880, 80 (1), 34.

Digitized by Google

Note on peculiar Quartz-Pseudomorphs found at the Owera Mine, Opitonui, North Island, New Zealand.

By Prof. G. H. F. Ulrich, F.G.S.

[Communicated by Professor Judd, C.B., F.R.S.]

[Read April 5th, 1898.]

THE Owera Mine is opened on a line of lode or reef consisting of small auriferous quartz veins traversing decomposed hypersthene-augite-andesite. The quartz of the veins is highly ferruginous, and full of little patches of brown hæmatite indicating decomposed pre-existing pyrite, remnants of which are occasionally observed. It is in connection with the veins in the soft country rock and near the surface that the pseudomorphs under notice are found, and it seems probable that they owe their origin to infiltration of silica into cavities left by removal of calcite, though none has the actual form of a crystal of that mineral, which, in fact, is quite absent at the place Yet the specimen (No. 2) found with some of the pseudo-crystals tends to support this supposed origin, the hollows and, more clearly, wax impressions of them showing that the removed crystals were scalenohedra. On some of the pseudo-crystals here and there an angle occurs, as measured by the hand-goniometer, approaching one or other of the terminal scalenohedral angles measured on a wax impression, but there is no further resemblance to this form. In general development and appearance, save colour, these pseudomorphs are much like the chalcedony "enhydros" found many years ago in the decomposed granite bottom beneath gold drift of a miner's claim in the Beechworth district, Victoria. There, however, many of the discovered pseudo-crystals enclosed fluid and moveable gas bubbles, while in none of those now under notice can such be seen. Yet it is probable that some of the kind do occur, and would therefore be true "enhydros." Two of the pseudo-crystals were cut in half. In one the interior cavity is virtually filled up, while the other shows, like many chalcedony geodes and Beechworth enhydros, a central cavity with drusy walls of quartz crystals. The appearance of a shining tracery on the

Digitized by Google

planes of the pseudo-crystals, judging from fine transverse striations, is doubtless due to the prism faces of small quartz crystals that lined the walls of the original cavities, while the dull parts between belong to quartz crystals grown into the cavities at all angles up to 90° to the walls. In fact, microscopic examination in convergent polarised light of thin sections, cut parallel to any of the planes of a pseudo-crystal, proves that the mass of each is compounded of small crystals of different optical orientation, and amongst these there are many cut at right angles to the principal axis, showing fine interference figures in which the positive optical character of the quartz can be especially well observed.

It may be mentioned in this connection that in other parts of the North Island gold fields, notably at Tirua, free silica produced through the decomposition of rhyolitic rocks has been deposited as "opal," forming a kind of granular rock in which many grains, here and there, show the colours of real precious opal; and some of these having been found of good size, mining for precious opal in the district has been spoken of as a possibly profitable industry.

Digitized by Google

NOTES AND COMMENTS.

WE note with regret the death, on March 30th, 1898, of Mr. James I'Anson, of Darlington, a well-known engineer who was for many years a member not only of the Mineralogical Society, but of its Council. In conjunction with Mr. E. A. Pankhurst he published in this Magazine an interesting paper on "Some Artificial Forms of Silica," illustrative of the structure of Agates and Chalcedonies.

The deaths are also reported of two eminent foreign mineralogists—Dr. Karl Ludwig Fridolin von Sandberger, who was elected a Foreign Member of this Society in the year 1879; and Dr. Christian Wilhelm Blomstrand, of Lund.

Dr. Sandberger was until recently Professor of Mineralogy and Geology in the University of Würzburg, where he was appointed in 1863. His name will always be associated with the remarkable advances in the study of ore-deposits, which were initiated by his researches. His view that the contents of metalliferous veins are derived by lateral secretion from the country rock was defended by careful observations upon mineral paragenesis and analyses of the minerals in the neighbourhood of the lodes, especially in the mining region of Schapbach. His *Untersuchungen über Erzgänge* was a most valuable contribution to the subject, and for the last 25 years his researches have been well known to all mineralogists. Prof. Sandberger was also the author of numerous papers on mineralogical and geological subjects, especially on fossil mollusca, published in the *Neues Jahrbuch f. Mineralogie* and in the geological journals. He died on April 11th, 1898, at the age of 72 years.

Dr. Blomstrand was Professor of Chemistry in the University of Lund, and his name is connected with numerous analyses, chiefly of Scandinavian minerals, compounds of the rare earths and of uranium, in which difficult subject he had no superior in skill and experience among contemporary chemists. He died on November 5th, 1897, in his 71st year.

Digitized by Google

Among recent appointments we note that of Mr. L. V. Pirsson to the Professorship of Physical Geology in Harvard University, and of Dr. J. L. C. Schroeder van der Kolk to the Professorship of Mineralogy in the Polytechnikum of Delft.

Professor Hintze, of Breslau, has, we are glad to see, entered upon the second volume of his great handbook, to which we have previously called attention. The first Lieferung, which has been recently published, contains accounts of diamond, graphite, sulphur, the arsenic group and iron, treated in the exhaustive and elaborate manner, both as regards description of properties and of localities, with which the silicates have already been described in the first volume.

All mineralogists will welcome the fourth edition of Professor Groth's *Tabellarische Uebersicht der Mineralien*, a work so well known to students and to curators of collections that it requires no recommendation beyond its own name.

The new edition differs from the last in having prefixed to each mineral group a general introduction which will be found of the greatest value to students as a survey of the most recent discoveries regarding the chemical constitution of minerals, and still more as an expression of the author's own interpretation. The crystallographic symmetry of each mineral is also more definite. The general arrangement of the book remains much the same as before.

We have received the following books :—

T. Fletcher. *The Commercial Uses of Coal Gas.* Fletcher, Russell and Co., Ltd. A supplement to the same author's *Coal Gas as a Fuel*, containing useful notes on the applications of coal-gas in a number of industries.

J. W. Leonard. *The Gold Fields of the Klondike.* T. Fisher Unwin. A book which instructs the fortune hunter how to get there and how to outfit.

Digitized by Google

OBITUARIES.

Alfred Olivier Des Cloizeaux.

PROFESSOR DES CLOIZEAUX, in whose death we had last year to deplore the loss of one of our most eminent Foreign Members, was born in 1817.

Imbued from childhood with a taste for mineralogy, he came in his student's days into contact with Lévy, Dufrénoy and Senarmont. After holding some minor appointments he was elected Maître de Conférences at the Ecole Normale in 1857, succeeded Delafosse as Professor at the Sorbonne in 1873, and at the Musée d'Histoire Naturelle in 1876, where he was made Honorary Professor in 1892.

In this brief notice it is not possible to do more than indicate in outline a small part of his extensive contributions to science. A complete list of publications is appended to the full and appreciative notice of Des Cloizeaux's life and works issued by his successor, Professor Lacroix, in the 20th volume of the *Bulletin de la Société Française de Minéralogie*, from which the above details are borrowed. His best known work is doubtless the *Manuel de Minéralogie*, which was originally undertaken with the intention of translating Brooke and Miller's edition of Phillips' *Mineralogy*, by which he had been much attracted. The work, however, assumed such large dimensions when he began to incorporate his own researches, that although the first volume was published in 1862, the first part of the second volume did not appear till 1874, and the second part in 1893. At the time when the first volume was issued, this book was quite remarkable for the immense amount of new information which it contained relating to the optical characters and the crystal measurements of minerals. Long tables of calculated and measured angles were a prominent feature of the descriptions, and the marvellous spherical projections which accompanied them added greatly to the utility of the book, and did much to render this mode of representation popular among mineralogists.

But Des Cloizeaux's most solid and enduring contributions to science were his memoirs on the optical properties of minerals, which really put quite a new and very powerful instrument of research into the hands

Digitized by Google

of investigators. These researches were originally begun under the direction of Biot; the best known among them are the discovery and definition of the dispersions in the monoclinic system, and the remarkable study of the variations introduced into the optical characters of crystals by change of temperature. Des Cloizeaux was the first to determine these characters and their variations for a very large number of substances, among which the most important were the felspars.

It is difficult now to realise how novel were the investigations which have since become familiar in all text-books of Mineralogy; to appreciate the profound influence which Des Cloizeaux's work exerted upon the science one must read again the text-books anterior to the date of his classic memoir on the use of the polarising microscope, and see how meagre were those optical data, without which no mineral description is now complete.

Among the more purely crystallographic memoirs the monograph on the form and structure of quartz stands as one of his most masterly works, and represents a vast amount of research. Among other contributions to Mineralogy, perhaps the best known and those which have exerted most influence on the science are the studies of the chondrodites, of microcline, of zoisite, and of the rhombic pyroxenes and amphiboles.

Des Cloizeaux was in 1870 first President of the Mineralogical Society of France, of which he was one of the founders; he was elected Member of the Institute in 1869, and President of the Academy of Sciences in 1889. He was a Foreign Member of this Society from the time of its formation.

His life was devoted with extraordinary assiduity to the study of minerals almost up to the day of his death, which took place on May 7th, 1897. H. A. M.

Emeritus-Professor M. Forster Heddle, M.D., F.R.S.E.

Matthew Forster Heddle was the younger son of Robert Heddle, of Melsettar, Hoy, Orkney, and was born there in 1828. The family were of Scandinavian descent, and it is doubtless to this strain that we may attribute much of the self-reliance, hardihood, energy and love of adventure which characterised Heddle in after life. These qualities were further developed by an out-door life, largely spent in clambering amongst the dangerous cliffs, or in boating alone amongst the geos, stacks and wild sea inlets, around his native island.

He was sent to Edinburgh to be educated, and he went first to the

Digitized by Google

Academy, and subsequently to Merchiston Castle, in connection with which schools there exist records of his stay in 1840-4. Many stories are told of him by his former schoolfellows. Most of these show that Heddle's well-known characteristics had begun to manifest themselves at an early period. One story illustrates his readiness to take up the cudgels in defence of any of the weaker of the boys who happened to be bullied by another, a congenial occupation in which Heddle's bodily strength and pluck were usually turned to good account. Others bring Heddle's histrionic talent into prominence, and tell us of his wonderful gifts as a romancer. Some of the anecdotes clearly show that, even as a lad, one of his most strongly-marked characteristics was that of a collector. It was this propensity which led to his becoming one of the founders of a School Natural History Society, whose chief business seems to have been, as usual in such cases, the making of collections of butterflies, birds'-eggs, shells and plants. It is said that young Heddle made a very good collection of Scottish plants, among which those of the mountains figured prominently. He gained a school prize for this herbarium, and it would appear from what can be gathered of this part of his early history, that he seemed at this period to be in a fair way of passing from the grade of a mere collector of plants to the higher stage of a student of botany. But an untoward accident occurred, which led to his energies being diverted from this into another channel. Heddle tells us that he lent the herbarium to a friend, who, when travelling across a stream with it, accidently let it fall into the water, whereby the collection became irretrievably ruined. He resolved, after this incident, to devote his energies to collecting something that could not be so easily spoiled, and henceforth became a collector of minerals. From that day forth to the end of his life nearly the whole of the time and energy at his command, and almost all the money he could obtain, were devoted to the one single object of collecting great quantities of the largest and finest specimens of minerals that were anywhere to be got. This eventually led to his amassing a remarkably fine general collection of minerals, comprising many specimens of unusually large size, and also to his getting together from the mountains, coasts and mines of Scotland, what is certainly the very finest local collection of minerals obtained from a single district by any one man. This Scottish mineral collection, which may be regarded as the crowning work of Dr. Heddle's life, eventually became, partly by purchase, and partly by gift, the property of the nation; and it is now fittingly displayed in the Gallery of Scottish Geology and Mineralogy in the Edinburgh Museum of Science and Art, where it was arranged chiefly under the direction of Dr. Heddle himself.

Digitized by Google

Returning to the chief events of Dr. Heddle's early life, it may be mentioned that from school he passed to the Edinburgh University, where he entered as a medical student, and where he obtained what was then, and still is, that best of all forms of education for a scientific career which training as a medical man confers upon a student. After going through the prescribed course of instruction, he went for a time to Clausthal, and then to Freiberg, where he studied chemistry, and extended his knowledge of mineralogy. Those who carefully study Dr. Heddle's scientific writings, and especially such as deal with geological topics, cannot fail to perceive in them many evidences of the extent to which his modes of thought were impressed by the German school of teaching of that period.

Returning to Edinburgh in 1851, he graduated M.D., taking as his thesis "The Ores of the Metals." After graduation he commenced medical practice in one of the poorer parts of Edinburgh. Those who knew Dr. Heddle are well aware that Nature had been bountiful to him in many ways. He might have done well as a lawyer, or as an actor, or as a novelist; he certainly was a born collector; and it is equally certain that he took the keenest possible interest in everything that related to Mineralogy; but assuredly he lacked some of those special gifts and acquirements whose possession leads to eminence in the medical profession. As this medical work proved entirely uncongenial to his tastes, he took the first possible opportunity of abandoning it, and of taking to work in its stead which was more to his mind.

It was soon after this (1856) that he went to Faroe, where he collected a large quantity of the fine zeolites which occur in the vapour cavities of the tertiary volcanic rocks there. These formed an important part of the basis of his general collection just referred to, and it was from the numerous duplicates then obtained that he afterwards drew a large supply of the materials used in acquiring other minerals by exchange. In 1858 he took an important share in bringing out a new Edition of Greg and Lettsom's *British Mineralogy*. In 1856 the Professor of Chemistry at the University of St. Andrew's became unable to carry on his teaching work, whereupon Dr. Heddle became his assistant, and in 1862 succeeded to the Professorship. While there he made, or had made, a large number of analyses of minerals, of which nearly 600 are exhibited in the Edinburgh Museum, alongside of the Scottish minerals to which they refer. He held the post at St. Andrew's, from first to last, for a period of 23 years.

Near the close of 1883 he was persuaded by a well-known financier to leave his professional duties and go to South Africa in connection with

Digitized by Google

some mines there. After taking due precautions in regard to possibilities in the future in connection with this new move—a proceeding in which Dr. Heddle's legal acumen stood him in very good stead—he relinquished his professorship, and went to South Africa. On his arrival, however, he found himself unable to endorse some of the statements which had been made regarding the prospects of the mines, and accordingly he left the country and returned home. Having proved successful in the lawsuit which ensued, he settled down again at St. Andrew's for the remainder of his life, devoting himself to his work amongst the Minerals of Scotland, and to the preparation of his long-promised book dealing with them.

Dr. Heddle's name is well known to the readers of the *Mineralogical Magazine* as the author of an extensive series of papers on the "Geognosy of Scotland." He also contributed to the *Proceedings of the Royal Society of Edinburgh* several other papers equally valuable, which were entitled "Chapters on the Mineralogy of Scotland." For one of these, dealing with the Rhombohedral Carbonates, he was awarded the Keith Medal in 1878. He was the author also of a large number of other papers dealing with Mineralogy and Geognosy; and he produced single-handed a geological map of Sutherland, which was for a long time the standard map of its kind, and upon which many subsequent writers have drawn for large supplies of both facts and ideas.

Dr. Heddle was at one time President of the Geological Society of Edinburgh. It was while he occupied this post that he was chiefly instrumental in urging the Government of the day to commence a Geological Survey of Scotland. He was the second President, and one of the founders, of the Mineralogical Society of Great Britain.

Probably the two chief works in connection with which Dr. Heddle's name will be best known to posterity will be his grand collection of Scottish Minerals in the Edinburgh Museum, and his book on the *Mineralogy of Scotland*, which he worked at for many years, and of which the manuscript and the drawings of crystals were nearly completed before his death. Dr. Heddle requested his friends, Mr. Alexander Thoms and the writer of this notice, to co-operate in completing the book, and in getting it published. This is being done, and by the end of the present year (1898) it will appear as a royal octavo volume of about 400 pages of letterpress, and illustrated with about one hundred and twenty plates of eight figures each, representing Scottish minerals, which were drawn almost entirely by the doctor's own hands.

Dr. Heddle died on the 19th November, 1897, and was buried in the grounds of the fine old Cathedral of St. Andrew's. J. G. Goodchild.

Digitized by Google

Albrecht Schrauf.

Although not more than 60 years of age at the time of his death, which took place on November 29th, 1897, the Professor of Mineralogy in the University of Vienna had been failing in health for a considerable time, and his decease can have been no surprise to his friends. Since 1896, when he lost the sight of one eye by the accidental entry of direct sunlight into the telescope of his goniometer, he had become partly incapacitated.

Educated in Vienna under the influence of Grailich, he was early attracted by the crystallographic methods of Miller, studied physics under von Ettingshausen, and so laid the foundation of what in after life proved to be his chief study, and the one on which in 1860-8 he published his well-known text-book, *Physikalische Mineralogie*. He became successively Assistant in the Hofmineralien Cabinet of Vienna, Professor of Mineralogy at Lemberg, Keeper of the Hofmineralien Cabinet, and in 1874 succeeded Reuss as Professor in the University. In his younger days he was closely associated with the Archduke Stephan, whose fine collection he studied for the preparation of a catalogue, and to whom he dedicated his *Atlas der Krystallformen*, which was intended to be a systematic representation of all the known forms of minerals. This work was never finished, but the five parts which were completed remain as a monument to his industry. The list of Schrauf's published books and papers (about 120) sufficiently indicates the wide range of his studies, and the active mind which has been lost to mineralogy by his death. His more prominent memoirs were devoted to (1) the physical and geometrical properties of crystals, (2) the atomic structure of crystals, and (3) mineral paragenesis. The last subject was always an important feature of his course. As a teacher Schrauf was extremely successful, and those who enjoyed the privilege of visiting his Institute under the personal guidance of the Professor were deeply impressed by the completeness of his system and educational methods. The details of Schrauf's life can be gleaned from a sympathetic biographical sketch published by one of his most distinguished pupils, Professor R. Scharizer, of Czernowitz.

His friends and pupils are desirous of raising a monument to his memory, and Dr. A. Pelikan is willing to receive subscriptions for this purpose at the Mineralogisches Institut, Universität, Wien. H. A. M.

Digitized by Google

REVIEWS.

Goldschmidt (V.). *Krystallographische Winkeltabellen.* Berlin, 1897.

Since the early editions of Phillips' *Mineralogy*, various text-books and works of reference have appeared, each containing more and more complete lists of crystal angles. But the number of angles that can be calculated between all the pairs of faces of such complicated crystals as occur in the mineral kingdom seems almost boundless, and it might be thought hopeless to make these lists even approximately complete.

This is, however, what is done by Dr. Victor Goldschmidt in the present volume, and it is only possible by means of the theodolite, or two-circle goniometer, of which he is an ardent champion. Every practical crystallographer will realise how much easier it is to identify the faces of a crystal by comparing their measurements with a table of angles than by calculating out the indices of each face from the measurements; but it may be that the angles actually measured are not those given in the available tables. With the two-circle goniometer, however, if the crystal be adjusted in the orthodox position, each face is fully defined by two angles which are directly read upon the goniometer circles. Dr. Goldschmidt has not hesitated to face the vast labour of calculating all the angles (about 22,000 in number) which belong to the known faces of minerals, a work which with the help of computers occupied him for nearly two years. The result is the present volume, with the help of which any student using the theodolite goniometer can identify any known face by a direct reading, and can determine new faces without much trouble. These tables will do much to popularise the new method of crystal measurement, which is now beginning to find many adherents. The writer can speak from personal experience of its utility in certain cases where measurement would be impossible without its aid.

H. A. M.

Fuchs (C. W. C.). *Anleitung zum Bestimmen der Mineralien.* 4th edition, revised by Dr. Reinhard Brauns. 234 pp. and 27 figs. Giessen: J. Ricker'sche Verlags-Buchhandlung. 1898.

The preparation of this fourth edition of Fuchs' *Introduction to the determination of Minerals* has been undertaken with excellent results by Dr. Reinhard Brauns, in succession to the late Prof. Streng.

Digitized by Google

Only comparatively slight alterations and additions have been made in the first parts of the book, dealing with the "Examination of Minerals with the help of the blowpipe and simple chemical reaction," and in the second part on microchemical reactions which was added by Streng in the preceding edition. The third part, however, consisting of the "Tables for the determination of Minerals by crystal form, physical characters and simple chemical reactions," has suffered a radical change. As indicated in the above heading, the first broad grouping of the minerals was according to the crystalline form. The objections to such a plan are too obvious to mention, and Prof. Brauns has wisely rejected it for an arrangement in which the chief weight is given to characters easily determinable on massive material. As the basis of his classification he has selected hardness in preference to fusibility, which is used for the same purpose in von Kobell's Tables as reproduced in Brush's *Manual of Determinative Mineralogy*. Hardness is not a very precise character of a mineral, but in the hands of students it is probably a more easily determinable and more reliable character than fusibility.

Minerals of approximately the same hardness are then divided into two groups, according as they do or do not possess metallic lustre. Colour and streak are the next marks of distinction, after which come cleavage, form, mode of occurrence, specific gravity and chemical characters.

Tables such as these no doubt fulfil a useful purpose, more especially, perhaps, as a means of instruction to the beginner, although they may not appeal so much to the more advanced student. The gradual tracking down of a mineral, for example, by rigorously following in all its detail such a systematic course of blowpipe and simple chemical tests as that given in the first part of the book, should form an excellent training for the student, until with increase of knowledge he learns to attain the same end by a less circuitous route.

The value of the book to the student has certainly been increased by the changes which Prof. Brauns has made in the present edition.

Digitized by Google

ABSTRACTS.

Composition of Hamlinite. (S. L. Penfield, *Amer. Journ. Sci.* 1897, IV, 313-316; and *Zeits. Kryst. Min.* 1897, XXVIII, 588). When hamlinite was first described in 1890 (Abstract, IX, 246) only a single specimen, with a few small rhombohedral crystals, was known, so that an analysis was not possible. The mineral has now been found with apatite, herderite and bertrandite on felspar and muscovite in Oxford Co., Maine. The small crystals are rhombohedral ($r\{100\}$ and $f\{\bar{1}11\}$) or prismatic ($m\{2\bar{1}\bar{1}\}$ and $c\{001\}$) in habit, $rr' = 88°41'$. Material could not be collected for analysis by hand-picking, so the specimens were powdered and the hamlinite separated by a heavy fluid; the accompanying apatite was then dissolved in dilute acid. The hamlinite so obtained, of sp. gr. 3·159—3·283, appeared to be pure when examined under the microscope. The mean of four partial analyses is—

P_2O_5	Al_2O_3	Fe_2O_3	SrO	BaO	H_2O	F	SiO_2	K_2O	Na_2O	Total (less O for F)
28·92	32·30	0·90	18·43	4·00	12·00	1·93	0·96	0·34	0·40	99·37

Deducting silica, alkalies, &c., as felspar and mica, this agrees closely with the formula $Al_3Sr(OH)_7P_2O_7$ or $[Al(OH)_2]_3(SrOH)P_2O_7$, in which strontium and hydroxyl are partly replaced by barium and fluorine respectively. In its chemical composition, hamlinite holds a unique position amongst minerals, as strontium and barium have never before been observed as essential constituents of a phosphate, and this is the first time a pyrophosphate has been recorded. L. J. S.

Grünlingite, a new mineral from Cumberland. (W. Muthmann and E. Schröder, *Zeits. Kryst. Min.* 1897, XXIX, 140-145). The bismuth telluride from Carrock Fells in Cumberland has usually been called tetradymite (or joseite), although the only analysis (I) which has been made of it (Rammelsberg, 1853) does not agree with the tetradymite formula. The present authors have re-examined the mineral, and find it to have

Digitized by Google

the composition shown in columns II and III, agreeing with the formula Bi_4S_3Te or Bi(S,Te), for which IV is the calculated composition.

	I.	II.	III.	IV.	V.
S ...	6·48	9·31	9·40	9·10	4·6
Bi ...	84·33	79·31	78·82	78·86	59·0
Te ...	6·73	12·82	12·66	12·04	36·4
	97·49	101·44	100·88	100·00	100·0

The irregular masses examined have a perfect cleavage in one direction. On the cleavage surfaces are cracks intersecting at about 60°, and the thermal conductivity figure is a circle, as observed by G. F. Herbert Smith; the crystal system is therefore probably rhombohedral, as in tetradymite. Sp. gr. 7·321.

In the same paper are given several analyses of Hungarian tetradymite, all of which agree closely with the formula $2Bi_2Te_3,Bi_2S_3=Bi_4Te_3S$, of which V is the calculated percentage composition. L. J. S.

Native Iron in the Coal Measures of Missouri. (E. T. Allen, *Amer. Journ. Sci.* 1897, IV, 99-104). Terrestrial iron has been stated to have been found in eruptive rocks, in river sands with gold and platinum, and in connection with organic matter, but the authenticated occurrences, which are not possibly artificial or meteoric, are very few. In the present paper native iron is described from Cameron, in Clinton Co., Weaubleau, Hickory Co., and Holden, Johnson Co., where it has been met with at depths of from 35 to 51 feet in the sandstone and clays of coal-measure borings. At Cameron the iron occurs in irregular fragments, weighing on an average 0·5 gram, the largest weighing 45·4 grams; it is soft (H = 4), very malleable, and almost silver white in colour. A marked laminated cleavage is present, but no Widmanstätten figures are developed by etching. When first extracted from the matrix the fragments are tarnished, but are free from rust; the sp. gr. varies from 7·43 to 7·88. Analysis shows the material to be almost pure iron (97·10 – 99·39 per cent. Fe), with small amounts of silica, carbon and phosphorus, but no nickel, cobalt or copper. The depth at which this iron occurs proves it to be of terrestrial origin, and the occurrence in coal-measures is suggestive of reduction. L. J. S.

Crystallised Stannite from Bolivia. (A. W. Stelzner, *Zeits. deutsch. geol. Ges.* 1897, XLIX, pp. 97, 131). A preliminary account of the

Digitized by Google

late Prof. Stelzner's researches on the silver-tin ores of Bolivia has already been published (Abstract, *Min. Mag.* X, 261; compare this vol. p. 14). In the present important paper (pp. 51-142) full details are given; this paper, with which a good map is issued, is practically a treatise on the minerals of Bolivia. One of the many items of interest is the occurrence of crystallised stannite in the mineral veins of Potosi.

Stannite has previously been considered to be cubic and tetrahedral, but the deltoid-dodecahedral crystals from Peru described by Breithaupt have been shown to be tetrahedrite (p. 75). The cubic crystals now described show the forms $\kappa\{111\}$, $\kappa\{11\bar{1}\}$, $\{110\}$, $\{100\}$, $\kappa\{hkk\}$; the two tetrahedra are equally developed, but differ in lustre. The colour is steel grey, with a yellowish tinge, and the streak is black. Blowpipe analysis of these crystals showed the presence of tin, copper, iron and sulphur, with traces of arsenic, the last, however, probably due to the presence of mispickel. An analysis of the massive mineral (containing some blende and pyrites), by E. Ziessler gave, after deducting 6·96 per cent. of gangue—

Sn.	Cu.	Fe.	Zn.	S.	Total.	Sp. gr.
27·50	29·00	13·75	0·75	29·00	100·00	4·495

The mineral was tested for germanium by Winkler, but with negative results. Heated in the closed tube, it decrepitates and gives off much sulphur; in this it differs from ordinary stannite. Associated with the crystals are pyrites, tetrahedrite, mispickel and quartz. L. J. S.

Stolzite and Raspite from Broken Hill, N.S.W. (C. Hlawatsch, *Ann. k.k. naturh. Hofmus. Wien*, 1897, XII, 33-41; and *Zeits. Kryst. Min.* 1897, XXIX, 130). Transparent, light yellow, red and brownish crystals of stolzite ($PbWO_4$) occur on galena, limonite and psilomelane. Five types of tabular and pyramidal crystals are described; $a:c=1:1{\cdot}15606$.

Raspite, a new dimorphous form of lead tungstate, is found on some of the stolzite specimens as brownish or yellow monoclinic crystals with a strong adamantine lustre. The crystals are flattened parallel to $a(100)$, and elongated in the direction of the axis of symmetry. They are always twinned on $a(100)$; $a:b:c=1{\cdot}3493:1:1{\cdot}1112$; $\beta=72°19'$. Cleavage $a(100)$ perfect. The index of refraction is very high, being about 2·6. Hardness, $2\frac{1}{2}-3$.

C. W. Marsh (*Trans. Australian Inst. Mining Eng.* IV, 154, 1897) gives several figures of crystals of "stolzite" from Broken Hill, some of which agree exactly with Hlawatsch's description of raspite. Compare also G. W. Card (*Records Geol. Survey N.S.W.* 1897, V, 122). L. J. S.

Digitized by Google

Calcite with organic colouring matter. (J. Fromme, *Jahresber. Ver. Naturwiss. Braunschweig*, 1897, X, 104-113). The nature of the colouring matter of allochromatic minerals, for example, quartz, calcite, fluorite, &c. is often difficult to determine, and in many cases not known. The author has examined translucent calcite of a chestnut-brown colour from veins in weathered gabbro in Radauthal, near Harzburg, in the Harz. The material is crystalline, and partly in well-developed acute rhombohedra. Iron and manganese are absent. The calcite is completely dissolved in hydrochloric acid, with emission of an asphalte-like smell, frothing, and separation of brown flocks. The filtrate is clear, and of a wine-yellow colour. The brown flocculent material agrees in all its characters with Berzelius' apocrenic acid—an acid related to humic acid, but containing no nitrogen. Another organic acid was isolated from the wine-yellow filtrate. The former is present in the calcite to the extent of 0·2310 per cent., and the latter 0·0135 per cent. Since these substances cannot be extracted from the calcite by reagents, they must exist in combination as the calcium salts.

From a solution of calcium bicarbonate containing an ammonia solution of apocrenic acid, artificial crystals of calcite were obtained. These are acute rhombohedra of a brownish yellow colour exactly like the natural mineral. In the natural formation of the mineral, carbonated rain water takes up ammonia and humic acids from the soil, and this in acting on the lime-felspars of the gabbro produces the coloured calcite.

L. J. S.

Crystalline Form and Chemical Composition of Boulangerite. (H. Sjögren, *Geol. Fören. i Stockholm Förh.* 1897, XIX, 153-167). Boulangerite occurs at Sala in Sweden as acicular and capillary masses embedded in coarsely crystalline calcite. On dissolving the calcite in acid, deeply striated needles are isolated which give good measurements in the prism zone, and in one case from an end face. The orthorhombic parameters agree with those of diaphorite:—

			$a : b : c$
Boulangerite	...	$5PbS.2Sb_2S_3$	0·5528 : 1 : 0·7478
Diaphorite	...	$5(Pb,Ag_2)S.2Sb_2S_3$	0·4919 : 1 : 0·7346

Analysis of this material by R. Mauzelius agrees with the above formula, thus showing the isomorphism of the mineral with diaphorite.

Pb.	Ag.	Zn.	Sb.	S.	Insol.	Total.	Sp. gr.
55·22	trace	0·06	25·54	18·91	0·23	99·96	6·185

Digitized by Google

The formula always accepted for boulangerite, namely $3PbS.Sb_2S_3$, was first given when the atomic weight of antimony was not exactly known. [Until 1855, Sb=129; Clarke (1897) gives 119·52]. A re-calculation of all the previous analyses shows that the majority agree with the formula $5PbS.2Sb_2S_3$, while none agree exactly with $3PbS.Sb_2S_3$. Embrithite is made a distinct species with the formula $10PbS.3Sb_2S_3$.

L. J. S.

Quartz barytes Rock from Salem, Madras. (T. H. Holland, *Records Geol. Survey, India*, 1897, XXV, 236-242). This rock forms a network of veins, from mere strings to several feet across, in the pyroxenic and other gneisses near Alangayam, in the Tirupatur taluk, Salem district, Madras Presidency. The average sp. gr. is 3·005, from which is calculated 69·2 per cent. of quartz and 30·8 of barytes. The rock, which has the appearance of a pegmatite, is presumably of igneous origin; from the magma, the barytes has crystallised as a rule before the quartz. The low sp. gr. (4·30) of the barytes crystals is accounted for by the presence of 4·01 per cent. of calcium sulphate. Such a mode of occurrence of barytes is unique. L. J. S.

Melting Points of Minerals. (R. Cusack, *Proc. R. Irish Acad.* 1897, V, 399-418). In the present paper a few improvements in Joly's meldometer are described, and the melting points of numerous minerals recorded. As described by Joly (*ibid.* II, 38, 1892; and *Chem. News*, 1892) the instrument consists of a platinum ribbon heated by a current of electricity, which may be gradually increased in strength by reducing the resistance in a rheostat. The temperature of the ribbon is given by its length, as measured by means of a lever and micrometer screw. The substance, of which the melting point is to be determined, is placed in the state of very fine powder on the ribbon, and observed with the aid of a microscope. The instrument is first calibrated with substances of known melting points.

The method gives readings to 2° of temperature, and forms an easy means of determining minerals. The melting points given for specimens of the same mineral species from different localities vary only slightly; a few of the lowest values are quoted below.

Actinolite	1272°	Adularia	1164°	Nephelite	1059°	Rutile	1560°
Hornblende	1187	Albite	1172	Leucite	1298	Brookite	1560
Augite	1187	Microcline	1169	Olivine	1363	Quartz	1425
Diallage	1264	Labradorite	1223	Kyanite	1090	Galena	727
Enstatite	1295	Epidote	954	Andalusite	1209	Blende	1049

L. J. S.

Digitized by Google

A Microsclerometer for determining Hardness. (T. A. Jaggar, Junr., *Amer. Journ. Sci.* 1897, IV, 399-412, and *Zeits. Kryst. Min.* 1898, XXIX, 262). A summary and classification is given of the various methods which have been employed in the determination of hardness. In the present instrument a cleavage tetrahedron of diamond is made to bore a hole of a certain depth (0·001 mm.) in an artificially prepared crystal section, the rate of rotation and weight on the point being kept constant. The depth of the hole is measured by microscopic focusing on a micrometer scale, and the number of revolutions of the diamond point required to produce this depth is taken as being proportional to the hardness. The relative hardnesses of members of Mohs' scale, as given below, show considerable variations, according to the method of observation.

	Jaggar.	Pfaff (1884).	Rosiwal (1892).	Auerbach.[1]
Gypsum	0·04	12·03	0·34	12
Calcite	0·26	15·3	2·68	80
Fluorite	0·75	37·3	4·70	96
Apatite	1·23	53·5	6·20	206
Orthoclase	25	191	28·7	220
Quartz	40	254	149	267
Topaz	152	459	138	456
Corundum	1000	1000	1000	1000

L. J. S.

Average Specific Gravity of Meteorites. (O. C. Farrington, *Journ. of Geology*, 1897, V, 126-130). From the weights and specific gravities of 142 meteorites, of which the fall has been recorded during the last 100 years, the average specific gravity of meteoric matter is deduced as 3·69.

L. J. S.

Spectrographic Analysis of Meteorites. (W. N. Hartley and Hugh Ramage, *Sci. Proc. Roy. Dublin Soc.* 1898, VIII. 703-710). By spectrographic methods the authors have previously detected the presence of the rare element gallium in several iron ores and bauxites. In meteoric irons, siderolites and stones of 18 falls, lines of the following elements have been identified: calcium, iron, nickel, cobalt, chromium, gallium, lead, manganese, silver, copper, sodium, potassium, rubidium and mag-

[1] *Ann. Phys. Chem.* LVIII, 357, 1896.

Digitized by Google

nesium. Copper, lead and silver are common constituents. Gallium is present in all the irons, but not in all the stones, examined. L. J. S.

On Leucite and Analcite and their mutual relations. (C. Klein, *Sitzungsber. k. preuss. Ak. Berlin*, 1897, XVI, 290-354). This paper is divided into three sections. I. is historical, and consists of an exhaustive discussion of previous work. II. is subdivided into two parts: the author in (*a*) describes the apparatus used for heating the crystals, and in (*b*) gives the results of his own observations. III. gives an epitome of the results, and the conclusions to be deduced. The symmetry of leucite is rhombic, but very nearly tetragonal, the bi-refringence being positive about the first mean line. The author thinks that if leucite changes its molecular-structure at 560°, the new arrangement varies with the three axes, depending on the faces and symmetry of the prevailing form. Analcite, on the other hand, is monoclinic, but very nearly tetragonal, the character of the bi-refringence being negative about the first mean line. In places this mineral is isotropic. The optical anomalies of leucite are caused by the crystals being formed at a high temperature, and the molecular structure changing on cooling. If analcite be heated in a damp atmosphere to about 200°-250° it becomes isotropic, but if to 500° the bi-refringence becomes stronger. The optical anomalies seem to be due to loss of water and changes in temperature and pressure.

G. F. H. S.

The Optical Anomalies of Analcite from Montecatini. (G. D'Achiardi, *Proc. Verb. della Soc. Toscana di Sc. Nat.* 1897, X, 267-276). The crystals have the form {211} well developed, sometimes associated with small faces of the cube. Sections parallel to (100), (111) and (211), cut both in the middle and near the surface of the crystals, were examined under the microscope. The observations are described, and are in agreement with those of Ben Saude, Brauns and Klein, showing that each crystal is composed of 24 monoclinic individuals having for base as many faces of the icositetrahedron. Sections cut near the middle of the crystals always showed an isotropic part in the centre. From this, and also since analcite on heating to 200°-250° in a damp atmosphere becomes isotropic, the author thinks the optical anomalies of this mineral are due to loss of water, probably the last phase of crystallisation. G. F. H. S.

Langbeinite, the first example of cubic tetartohedrism in minerals. (O. Luedecke, *Zeits. Kryst. Min.* 1898, XXIX, 255-261). Borings were

Digitized by Google

made at Huy, near Anderbeck, for potassium salts. Dr. Zuckswerdt published in 1891 an analysis of salt from a depth of 230 metres, and showed that the formula is $K_2Mg_2S_4O_{12}$. This analysis was made on material mixed up with as much as 47·85 per cent. of NaCl, but later analyses on carefully selected material agree closely with the formula. The author is aware of only three crystals existing. He describes one which clearly shows tetartohedral symmetry, and gives the crystallographic details. The forms present are {100}, {111}, {1$\bar{1}$1}, {2$\bar{1}$1}, {2$\bar{2}$1}, {310}, {210} and perhaps {920}, and finally {110}. In this class of symmetry there are four trigonal axes of symmetry which are polar in character. This property was shown by etching; the negative tetrahedron faces showed worm-shaped figures, whilst the positive faces were unaffected. The refractive indices were found to be $n_{Li} = 1·5281$, $n_{Na} = 1·5329$, $n_{Tl} = 1·5343$. Sp. gr. is 2·827; fracture conchoidal; lustre vitreous. The mineral rapidly absorbs moisture from the air, and becomes opaque. G. F. H. S.

A Quartz double-plate. (F. Stöber, *Zeits. Kryst. Min.*, 1898, XXIX, 22-24). The double-plate consists of two quartz sections cut parallel to the axis, which touch in a direction making an angle of 45° with the axes, so that these are at right angles. The most convenient thickness is that—about ·064 mm. which gives between crossed nicols the violet of the second order. The plate, after being protected by cover-glasses, is placed near the cross wires in the eye-piece, so that the line of separation coincides with a wire. If the analysing nicol be above the eye-piece, this plate can be used for the following determinations:—

1. Weak bi-refringence.
2. Stauroscopic measurements.
3. Character of the bi-refringence in thin mineral sections if the position of the axes in the two halves of the plate is known.
4. The planes of symmetry of the optical ellipsoid.
5. The position of the optic axes in parallel polarised light.

G. F. H. S.

A simple Theodolite-Goniometer, and its employment in stauroscopic determinations. (F. Stöber, *Zeits. Kryst. Min.* 1898, XXIX, 25-32). The author shows how such an instrument can be easily constructed by the addition of a vertical double ring to an ordinary Fuess goniometer. The double ring is mounted on a cylindrical axis, which takes the place of the axis attached to the original crystal holder. The inner ring,

Digitized by Google

which is graduated, can turn inside the outer, to which is attached a vernier reading to minutes, about a horizontal axis. The new crystal holder is clamped to the inner ring, and projects in a radial direction; it is capable of extension in the same direction, and the crystal may thus be accurately centred. The necessary adjustments are described. The instrument is used in the ordinary way, with the telescope and collimator at right angles for about 300° of the horizontal scale. For the remaining 60° the ring will be in the way of the collimator or the telescope. By moving the telescope through 40° this difficulty may be overcome. Of course half this value must be added to or subtracted from the azimuthal reading, as the case may be.

The instrument can be conveniently used for stauroscopic determinations by removing the crystal holder and fitting a glass plate into the inside of the ring. To this the crystal section is affixed by means of a pair of springs. Nicol prisms are fitted to the telescope and collimator on the sides next to the crystal section. G. F. H. S.

Some Minerals in the neighbourhood of Schlaining. (A. Schmidt, *Math. és term. tud. Ertesitő*, Buda-Pesth, 1897, 15; and *Zeits. Kryst. Min.* 1898, XXIX, 198-212). After a discussion of former work on the subject, the author gives a detailed account of his own studies. Six crystals of stibnite from Bergwerk (Bánya) are figured and described, and the measurements given. The following new forms were found: {034}, {40.19.10}, {10.9.15}, {563} and {12.19.3}. Crystals of the same mineral from Schlaining are similar in habit, having {343} prominent, but, being covered with a crust, could not be accurately measured. Some small bright crystals of sulphur were found on the specimens. Four such are described, and the measurements given. They appear to be the result of the decomposition of the stibnite. The other minerals met with are gypsum, calcite in small crystals (showing the form {110}), barytes in thin tablets (with the forms {001}, {110}, and very small {104}, {102}), and a crust of cinnabar. G. F. H. S.

Note on Tuscan Minerals. (G. D'Achiardi, *Proc. Verb. Soc. Tos. di Sc. Nat.* 1897, X, 210-4.) 1. Epsomite from Jano. Some crystals are fairly large, and stand alone; others are embedded in a crystalline crust of chalk. Hemihedrism is well shown by the different developments of faces of the same forms. The axial ratios agree with those found by Miller. The optical characters agree with those determined by Des Cloizeaux. Transparent crystals often show air bubbles with liquid

Digitized by Google

inclusions, and the faces are corroded. The mineral is probably due to water rich in sulphur attacking miemite, resulting in chalk and epsomite.

2. Cerussite from Valdaspra. Associated with the aurichalcite from this district are numerous small crystals which on microscopic and chemical investigation were found to be cerussite with forms probably {110}, {100}, {010}, {111}, and {011}.

3. A specimen of pyrites from Carrara shows two cubes in juxtaposition twinned about (320). G. F. H. S.

On the reproduction of the diamond. (Q. Majorana, *Rend. della R. Acc. dei Lincei*, 1897, VI, 141.) Amorphous carbon has a density less than 2, graphite has a density of 2·5 and diamond of 3·5. To produce diamonds from amorphous carbon a high temperature and a great pressure is required. Pieces of carbon of the kind used for the arc light—sugar is preferable, but would not be compact enough—were heated between the poles of an electric arc. A current of 100 volts and 25 ampères was used. The carbon is fixed to a small steel piston rod 1 cm. in diameter, which fits into a cavity in a steel block. On the other side the rod joins a larger piston, which fits a cylinder hermetically sealed at one end. The apparatus is calculated to withstand a pressure of about 5,000 atmospheres. Gunpowder is placed in the cylinder, and exploded electrically. The pressure thus excited is exerted on the heated carbon by means of the piston. The resulting mass, which has a density of 2·28, is reduced by Berthelot's method as modified by Moissan, until finally some small particles are evolved; these are usually opaque, but sometimes transparent. Both kinds have the density, hardness and crystalline structure of diamond, and are not affected by acids. G. F. H. S.

Digitized by Google

Digitized by Google

Digitized by Google

THE MINERALOGICAL MAGAZINE
AND
JOURNAL
OF THE
MINERALOGICAL SOCIETY.

No. 55. APRIL, 1899. Vol. XII.

Plagionite, Heteromorphite and Semseyite as Members of a Natural Group of Minerals.

By L. J. Spencer, M.A., F.G.S.,
With Analyses by G. T. Prior, M.A., F.G.S.,
Assistants in the Mineral Department of the British Museum.

[Read November 15th, 1898.]

In a recent number of this Magazine (1897, XI. p. 192) a paper by me on "The Crystallography of Plagionite" gives the results of goniometric measurements and specific gravity determinations made on crystals of plagionite from Wolfsberg in the Harz; it was also suggested on crystallographic grounds that the mineral from Arnsberg in Westphalia described by Pisani as heteromorphite was identical with plagionite: but as no quantitative chemical analyses were made on the material measured, these results were not altogether satisfactory.

Three specimens, which on account of their crystalline form and qualitative chemical composition were at that time considered to be plagionite, were therefore selected for further examination, with the result that only one of them was found to agree also in quantitative chemical composition and specific gravity with the original plagionite: of the two others, one agreed in these respects with Pisani's determinations for heteromorphite, and the other with semseyite.

Digitized by Google

These three minerals, therefore, although apparently the same, or nearly the same, in crystalline form, differ considerably in the proportions of lead to antimony which they contain.

In the first three sections below, each of the three specimens is described in detail, and in a fourth section the relations between them are discussed.

I. Plagionite from Wolfsberg in the Harz.

This specimen is a small confused group of bright crystals, without matrix; it has already been mentioned in the Magazine (XI. p. 194) as weighing 2·6642 grams and having a specific gravity of 5·57. On the surface are a little reddish-brown "tinder ore" and one or two very minute brittle needles, possibly of stibnite.

The colour of the mineral is iron-black, with perhaps a tendency to lead-grey; bright metallic lustre; opaque. The streak is black and in part shining (or, on unglazed paper, dull). The fracture is uneven, and there is a good cleavage parallel to $n\{111\}$. Brittle; hardness $=2\frac{3}{4}$.

The crystals are well developed, and the largest is about 7 mm. across. They are tabular in habit (Fig. 1), being flattened parallel to the basal plane $c\{001\}$; other important forms are the large negative pyramids $\{hhl\}$, and the smaller orthopinacoid $a\{100\}$, all of which are deeply striated and rounded parallel to their intersections with the basal plane, as is invariably the case in plagionite. These crystals were, therefore,

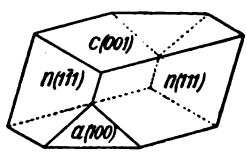


Fig. 1

badly adapted for measurement, but they were the best that could be sacrificed for combined crystallographic and chemical examination; they were comparatively large, apparently pure, and free from any drusy surfaces. The forms on the best crystal were determined by the approximate measurements to be: $c\{001\}$, $a\{100\}$, $e\{112\}$, $l\{223\}$, $n\{111\}$, $x\{221\}$, $m\{110\}$, also narrow, badly defined, positive pyramids $\{hhl\}$, rounded orthodomes near the positions of $\{\bar{7}01\}$, $\{\bar{7}02\}$ and $\{\bar{7}03\}$, and small indeterminable positive pyramids $\{\bar{h}kl\}$.

In collecting material for analysis, the cleavage and the striation of the faces were important guides. It was examined with a lens and under

Digitized by Google

the microscope, but no other mineral was detected. Attempts were made to measure each fragment which showed crystal faces; the following rather unsatisfactory angles were obtained from five fragments:—

	Calculated.[1]	Measured.
$ce = 001 : 112$	25° 40′	24½°, 26½°.
$cn = 001 : 111$	41° 8′	40°, 40½°, 42°, 42°, 42½°, 43°.
$cx = 001 : 221$	55° 54′	54½°, 56°, 56°, 56°, 56°.
$cm = 001 : 110$	78° 12½′	80°, 80°.
$ca = 001 : 100$	72° 28′	72°, 74°.

The specific gravity (weight of 1 cc.) of the material analysed was 5·50 at 22° C. The method of analysis was as previously used for andorite (this Magazine, 1897, XI. p. 290), the mineral being decomposed in a current of dry chlorine. The following results[2] were obtained by Mr. Prior on 0·6002 gram:—

		Atomic ratios.		Calcd. for $9PbS.7Sb_2S_3$.
Pb	41·24	·2008	9	41·29
Sb	37·35	·3125	14·01	37·38
S	21·10	·6629	29·7	21·33
	99·69			100·00

These results agree closely with the formula $9PbS.7Sb_2S_3 = Pb_9Sb_{14}S_{30}$. This is midway between the original formula $4PbS.3Sb_2S_3$, given by H. Rose in 1833 for plagionite, and that now usually accepted, namely, $5PbS.4Sb_2S_3$, which was proposed by Rammelsberg in 1860 (*Min.-chem.*, p. 68). The previous analyses of Wolfsberg plagionite are quoted on p. 65, where the calculated percentage compositions are also given.

II. Heteromorphite from Arnsberg in Westphalia.

This mineral has already been mentioned in the Magazine (1897, XI. pp. 194-5), where it is stated that "the curved, indistinct crystals were found on measurement to be plagionite. One of the three crystals measured showed the forms *c a p e n*." Pisani,[3] who first described the mineral, stated that the crystals, from their appearance and qualitative chemical composition, were at first considered to be plagionite; but when

[1] G. Rose, *Pogg. Ann.* 1833, XXVIII. 421.

[2] The atomic weights used in this paper are those given by F. W. Clarke (*Smithsonian Miscell. Collections*, 1897, No. 1075). Here Sb = 119·52 and Pb = 205·36, these being slightly lower than the values usually adopted. Previous to 1855, Sb was taken as 129, which accounts for some of the differences in the old formulæ.

[3] *Comptes Rendus*, 1876, LXXXIII. 747.

Digitized by Google

his quantitative analyses gave the formula $7PbS.4Sb_2S_3$, he concluded that the mineral could not be plagionite, and he then considered it to be crystallised heteromorphite, as forming probably a species distinct from jamesonite.

Here, owing to confusion of terms, it will be well to give a short historical review of jamesonite and heteromorphite. The prismatic Cornish mineral with a perfect end-cleavage was first noticed by Mohs in 1820; Haidinger in 1825 measured the prism angle, and gave the name jamesonite; and H. Rose in 1826 found the formula to be $3PbS.2Sb_2S_3$. In 1829 Rose found the federerz (feather ore) of Wolfsberg, which had previously been considered as stibnite, to have the formula $2PbS.Sb_2S_3$. This he established as a new species distinct from jamesonite. Twenty years later (1849) Zincken and Rammelsberg described a compact mineral from Wolfsberg also having the formula $2PbS.Sb_2S_3$, which they considered to be identical with Rose's federerz, but this name being inappropriate for their compact variety, they proposed the new name heteromorphite. Jamesonite and heteromorphite (=federerz) remained as distinct species until 1860, when Rammelsberg united them under the name jamesonite with the formula $2PbS.Sb_2S_3$; Rose's original formula, $3PbS.2Sb_2S_3$, being explained as due to the presence of admixed stibnite. This has since been followed in all the text-books.[1]

Zincken and Rammelsberg gave no reasons, beyond the similarity in chemical composition, for the statement that their compact mineral was identical with federerz, and indeed it may really have belonged to the plagionite-semseyite group rather than to the dimorphous group of acicular minerals into which zinckenite, jamesonite, plumosite (=federerz), boulangerite, and possibly meneghinite, may be provisionally brought together. The compact nature with platy separation, and the absence of iron (which is always present in plumosite and jamesonite to the extent of 2—3 per cent.) perhaps favour the latter view. If this be correct, then Pisani was justified in applying the name heteromorphite to the plagionite-like mineral from Arnsberg; and under the circumstances it seems best to follow him in the use of the name, even although it cannot be definitely proved that the heteromorphite of Pisani is identical with the heteromorphite of Zincken and Rammelsberg.

---

[1] As a result of this the old jamesonite formula $3PbS.2Sb_2S_3$ has been forgotten, but has turned up again under the later names warrenite and domingite! We are at present examining these minerals, and have already made an analysis of measured crystals of Bolivian jamesonite, which, as in previous cases with crystallised and cleavable jamesonite, does *not* give the formula $2PbS.Sb_2S_3$.

Digitized by Google

It therefore seemed necessary to make an analysis on material of which the crystallographic data had been determined. The Arnsberg specimen selected for this purpose was one of the two previously examined. It consists of a fairly large mass of compact material, the cavernous surface of which is covered with numerous small crystals in crystallographic continuity with the massive material below. The massive material is crystalline throughout, as shown by the numerous cleavages on the fractured surfaces, and to all appearance it is the same substance as the crystals. The only other minerals on the specimen are one or two small isolated crystals of black blende and an embedded angular fragment of black quartzite.

The plagionite-like mineral is dull iron-black, but crystals in freshly opened cavities have a bright metallic lustre; the streak is black, and in part shining; H. = 2½.

Although the crystals are small (about 1 mm. across) and indistinct, yet there is no mistaking the peculiar habit, striation of the faces, and good cleavage, so characteristic of plagionite. Few if any are tabular parallel to the basal plane, as is often the case in the Wolfsberg plagionite,

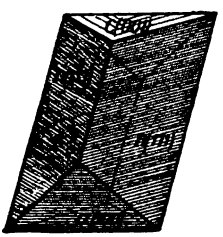


FIG. 2.

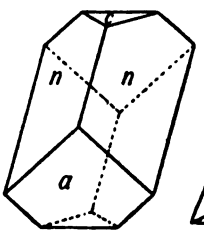


FIG. 3.

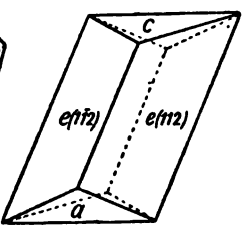


FIG. 4.

but they are elongated in the direction of the pyramid edges [hhl, $h\bar{h}l$] as shown in Figs. 2—4.[1] The striations and roundings are the same as before, but much more pronounced; and, owing to the grouping of the crystals in more or less parallel position, the zone of pyramids and the orthopinacoid are more often twisted than simply rounded, as in the saddle-shaped crystals of dolomite. The basal plane is usually smoother, but is often represented by different areas which are inclined at several

[1] Pisani (*loc. cit.*) describes the habit of the crystals as resembling that of mispickel, with an obtuse dome, or of adularia with $c\{001\}$ and $x\{\bar{1}01\}$. with deeply striated summits and oblique striations on the prism faces. He also mentions that the system is probably monosymmetric.

Digitized by Google

degrees to each other. It was therefore very difficult to obtain any satisfactory measurements; only eight of the numerous fragments placed on the goniometer gave any results at all.

	Calculated. Plagionite.	Calculated. Semseyite.	Measured.
001 : 114	$cp = 14° 12'$	17° 50½′	14°.
001 : 112	$ce = 25° 40'$	30° 58′	28°5′, 32°1′, 32°31′, 32°51′, 32½° (or 34° 0′).
001 : 111	$cn = 41° 8'$	$cp = 46° 35'$	40°50′ or 43°3½′ (cleavage; *c* gives a double image), 41°12′ or 46°18′, 40°57′, 44°56′, 44° or 45°.
001 : 100	$ca = 72° 28'$	$cn = 71° 4'$	71°27′, 72°.
111 : 1$\bar{1}$1	$nn' = 59° 11'$	$pp' = 66° 19'$	65°, 65° (cleavage).

Although these measurements are very bad, varying in some cases more than 5°, still they show that the angles of the Arnsberg mineral are of the same general character as the angles of plagionite; and on this account the mineral was previously referred to plagionite.

The material collected for analysis consisted only of crystals and the crystalline material directly in contact with them, and was all taken from the free surface of the specimen. The results obtained by Mr. Prior with 0·5677 gram are given below. Iron and arsenic were absent. Specific gravity of the material analysed = 5·73 at 23° C.

		Atomic ratios.		Calcd. for $11PbS.6Sb_2S_3$.
Pb	48·89	·2381	11	48·93
Sb	31·08	·2600	12·02	31·07
S	19·36	·6082	28·1	20·00
Zn	0·18			
Cu	0·10			100·00
	99·61			

This analysis agrees with Pisani's determinations (see p. 65), though the lead is one per cent. higher than found by him. Pisani gave the ormula $7PbS.4Sb_2S_3$; as shown by Rammelsberg (*Min.-chem.* 1886, p. 138), his analysis agrees better with $9PbS.5Sb_2S_3$. The above analysis gives $11PbS.6Sb_2S_3 = Pb_{11}Sb_{12}S_{29}$, but the sulphur is rather low.

III. Semseyite from Wolfsberg in the Harz.

The specimen described in this section was selected for analysis on account of the high specific gravity 5·99 (as determined with the

Digitized by Google

hydrostatic balance for the group of crystals weighing 10·6430 grams). This also had been catalogued with the plagionites; the high specific gravity being, at the time, thought to be possibly due to a kernel of some heavier mineral, such as galena.

No matrix is present, but there is a little reddish "tinder ore" and "feather ore"[1] on the surface, and in a few small crevices in the interior. Although the mass was broken open and submitted to very careful examination, these were the only minerals found.

The crystals of the plagionite-like mineral are much larger (averaging 1 cm. long) than observed on any of the other specimens which have been catalogued as Wolfsberg plagionite. They are grouped for the most part in more or less parallel position, and are of the habits shown in Figs. 2—4 (p. 59). The crystals, although very distinct in form and habit, are sometimes distorted and twisted, even more so than in the Arnsberg mineral; further, the surfaces are rough and drusy, and the whole appearance of some of the crystals points to their being built up of smaller individuals in radiated rather than in parallel position. Of the forms which can be distinguished: $c\{001\}$ is the most even, but is usually small and sometimes absent; $a\{100\}$ is very rough, and often rounded in two directions; the pyramids are sometimes fairly even, and the thicker and the flatter prismatic habits shown in Figs. 2 and 4 respectively are easily to be distinguished. At other times the pyramids merge into each other and the basal plane, forming a twisted surface. The striations are the same as before.

Attempts were made to measure several crystals and fragments, but variations of over 10° were obtained, and no definite angle can be given. The most satisfactory measurements were obtained from the pyramids across the plane of symmetry. This angle $(hkl):(\bar{h}kl)$ gave various values between the extremes 33° and 82°.

The colour of the mineral is iron-black, with dull metallic lustre, which however is brighter on fresh fractures; the streak is black and in part shining. The mineral is brittle; H.=2½. The pyramidal cleavage is good, and the fracture uneven, with sometimes a more or less granular appearance. The difference between the more or less even cleavage surfaces and the uneven fractures with the granular appearance is more marked when fragments, illuminated with the aid of a Lieberkuhn, are examined under the microscope. Beyond this difference there was

[1] In matted fibres, which are straight and not flexible; it contains lead, antimony and sulphur.

Digitized by Google

nothing that suggested the presence of more than one kind of mineral, and this is not inconsistent with the material being all of one kind, since the cleavage does not give a closed form.

The material collected for analysis gave sp. gr. = 5·92 at 22° C. for the fine powder. In the following analysis by Mr. Prior, the antimony and lead were determined by decomposing 0·6953 gram of the mineral in chlorine, and the sulphur by fusing another portion weighing 0·3278 gram with sodium carbonate and potassium nitrate.

		Atomic ratios.		Calcd. for $21PbS.10Sb_2S_3$.
Pb	51·84	·2524	21·06	51·79
Sb	28·62	·2395	20	28·71
S	19·42	·6100	50·94	19·50
	99·88			100·00

This agrees closely with the formula $21PbS.10Sb_2S_3 = Pb_{21}Sb_{20}S_{51}$. Both the lead and the antimony differ by about one per cent. from the amounts required by the formula $2PbS.Sb_2S_3$ (see p. 65).

This mineral, then, although closely resembling plagionite and the Arnsberg mineral in appearance and crystalline form, contains 10—11 per cent. more lead than the former, and 8 per cent. more than the latter, whilst it contains only 1·3 per cent. less lead than semseyite.

The name semseyite was given by Prof. J. A. Krenner[1] to small, grey, tabular crystals from Felsőbánya in Hungary, which are strikingly similar to the Wolfsberg plagionite[2] in appearance, habit and cleavage, but differ from it in the proportion of lead to antimony, the specific gravity, and also slightly in the crystal angles. Analysis by L. Sipőcz gave the formula $7PbS.3Sb_2S_3 = Pb_7Sb_6S_{16}$; sp. gr. = 5·9518. Only three measured angles are given, but these do not agree with the parameters[3] as given by Krenner, and it is difficult to know exactly what value to attach to them.

The crystals described in this section may then be called semseyite, since they agree with this in chemical composition, specific gravity, and in the habit and cleavage. Also the approximate measurements, 33° and

---

[1] *A Magyar tudományos Akadémia Értesitője*, Budapest, 1881, XV. 111–3. German abstracts are given in *Zeits. Kryst. Min.* 1884, VIII. 532–3, and *Ungarische Revue*, 1881, p. 367.

[2] In fact, the specimens appear at one time to have been labelled as plagionite, since M. Tóth (*Minerals of Hungary*, Budapest, 1882, p. 385) gives plagionite from Felsőbánya, on the authority of the Hungarian National Museum.

[3] The parameters and angles calculated by Dana from Krenner's three measured angles are here adopted.

Digitized by Google

82°, given above, are near to $ss'(113 : 1\bar{1}3) = 33°50'$ and qq' $(221 : 2\bar{2}1)$ $= 81°2'$ of semseyite. The corresponding extreme plagionite angles are: pp' $(114 : 1\bar{1}4) = 21°14'$ and yy' $(331 : 3\bar{3}1) = 83°29'$; also ee' $(112 : 1\bar{1}2) = 37°57'$.

Another specimen of Wolfsberg "plagionite" consists of numerous small crystals of the same habit as the above: they are, however, much more distorted and less distinct, and form globular aggregates,[1] the surfaces of which are defined by the rounded and striated orthopinacoids $a\{100\}$. Penetrating the whole group are one large, and several smaller, thin-tabular crystals of bournonite. On the surface of the specimen are small quantities of "tinder ore" and a few minute crystals of copper pyrites and calcite. The specific gravity of the whole group (weighing 29·4529 grams) is 5·99. Since all the accompanying minerals have specific gravities lower than this, the plagionite-like mineral must have a specific gravity slightly higher.[2] Qualitative analysis showed the presence of only lead, antimony and sulphur. On one small fragment the angle from the basal plane to the cleavage was measured as 46°49', also for the natural faces $cp = 47°$. This specimen is therefore semseyite. Curiously enough, this specimen, and another with isolated crystals of the same prismatic habit on a matrix of quartz, were acquired by the British Museum (from Dr. Fischer in 1864) labelled as crystallised heteromorphite of Rammelsberg.

IV. The Relations of the Plagionite-Semseyite Group.

As already stated, both Pisani and Krenner had remarked on the great similarity of the crystals of the Arnsberg heteromorphite and of semseyite with those of the Wolfsberg plagionite. The form, striation of the faces, and cleavage are the same for all three minerals, and the approximate measurements which could be obtained from the material described above are not sufficient to distinguish between them. Pisani gave no measurements, and the data given by Krenner for semseyite only differ essentially from the plagionite constants in the greater length of the vertical axis, in the ratio of 4 : 3.

---

[1] Such globular aggregates of "plagionite" from Wolfsberg have already been described by Kenngott (*Sitz.-ber. Akad. Wien*, 1855, XV. 236; XVI. 160). He also gives figures illustrating the prismatic habit.

[2] Taking the sp. gr. of bournonite to be 5·8, and estimating its volume (about 1cc.) by measuring the size of the crystals, the sp. gr. of the semseyite is calculated as about 6·0.

Digitized by Google

	a : b : c	β	c : 111 (cleavage).
Plagionite[1] ...	1·1861 : 1 : 0·8410	72°28′	41° 8′
Semseyite ...	1·1442 : 1 : 1·1051	71° 4′	46°35′

Since the chemical composition and specific gravity of the Arnsberg heteromorphite are between those of plagionite and semseyite, it might be expected that the vertical axis should also have some intermediate value. The measurements given above (p. 60) are however too unsatisfactory to show whether this is the case or not, but some of these angles lie between the corresponding plagionite and semseyite values.

The corresponding forms occurring on the three minerals are compared in the following table. All the observed heteromorphite and semseyite forms, but not all the plagionite forms, are given. The parametral plane is the direction of good cleavage for all.

Plagionite	$c001$	$a100$	$p114$	—	112	$n111$	$x221$	—	$s\bar{1}12$
Heteromorphite	$c001$	$a100$	$p114$	—	$e112$	$n111$	—	—	—
Semseyite	$c001$	$a100$	—	$s113$	—	$p111$	$q221$	$t\bar{1}13$	—

The crystals of plagionite, heteromorphite and semseyite described above show a difference in habit, in the first being tabular (Fig. 1), and in the last two prismatic (Figs. 2—4). The plagionite crystals measured by Rose and Luedecke, and most of the crystals of which measurements have previously been given in this Magazine, were also tabular in habit. But it is doubtful whether this difference in habit is sufficient for purposes of discrimination. Most crystals are unsuitable for accurate measurement, so that the only methods of determination are quantitative analysis or to take the specific gravity. The crystals are, however, usually small and scattered over a matrix of quartz, &c., and to collect sufficient material for their determination would mean the destruction of the rare specimens.

In order to compare the chemical composition of members of the group, all the published analyses are brought together and arranged below according to the percentage of lead. Zincken and Rammelsberg's heteromorphite from Wolfsberg has also been added for the reasons stated above (p. 58).

---

[1] G. Rose's parameters (*Pogg. Ann.* 1833, XXVIII. 421) are here given, since they are presumably determined on the same material as analysed by his brother, H. Luedecke's (1883) measurements were not made on analysed material.

Digitized by Google

			Pb.	Sb.	S.		Total.	Sp. gr.
Plagionite.	Schultz (1860)	Wolfsberg	39·36	37·84	21·10	Cu 1·27	99·57	—
	Rose (1833)[1]	,,	40·52 40·62	37·94 —	21·53 21·89		99·99	(5·4)
	Kudernatsch (1836)	,,	40·81					
	Crystals		40·98	[37·53]	21·49		100·00	
	Prior (p. 57)	,,	41·24	37·35	21·10		99·69	5·50
Heteromorphite.	Pisani 1876)[2]	Arnsberg	47·86 48·1	31·20	19·90	Zn 0·60	99·56	5·59 to 5·73
	Poselger (1847)[3]	Wolfsberg	48·48	32·98	20·32		101·78	5·68
	Prior (p. 60)	Arnsberg	48·89	31·08	19·36	Cu 0·10 Zn t·18	99·61	5·73
Semseyite.	Prior (p. 62)	Wolfsberg	51·84	28·62	19·42		99·88	5·92
	Sipőcz (1881)[4]	Felsőbánya	53·16	26·90	19·42	Fe 0·10	99·58	5·95

Although these analyses fall into three well-marked groups, yet they are all different, and none of them give simple formulæ. The calculated percentage compositions corresponding with the various formulæ are added for comparison with the analyses. $2PbS.Sb_2S_3$ is also given, but it agrees with none of the analyses.

		Pb.	Sb.	S.	Pb. : Sb.
Plagionite.	$5PbS.4Sb_2S_3 = Pb_5Sb_8S_{17}$ ...	40·68	37·88	21·44	1 : 1·60
	$9PbS.7Sb_2S_3 = Pb_9Sb_{14}S_{30}$	41·29	37·38	21·33	1 : 1·55
	$4PbS.3Sb_2S_3 = Pb_4Sb_6S_{13}$ ...	42·07	36·73	21·20	1 . 1·50
Heteromorphite.	$7PbS.4Sb_2S_3 = Pb_7Sb_8S_{19}$ ...	47·94	31·89	20·17	1 : 1·14
	$9PbS.5Sb_2S_3 = Pb_9Sb_{10}S_{24}$...	48·54	31·39	20·07	1 : 1·11
	$11PbS.6Sb_2S_3 = Pb_{11}Sb_{12}S_{29}$	48·93	31·07	20·00	1 : 1·09
	$2PbS.Sb_2S_3 = Pb_2Sb_2S_5$ ...	50·77	29·55	19·68	1 : 1
Semseyite.	$21PbS.10Sb_2S_3 = Pb_{21}Sb_{20}S_{51}$	51·79	28·71	19·50	1 : 0·95
	$9PbS.4Sb_2S_3 = Pb_9Sb_8S_{21}$ ...	53·22	27·53	19·25	1 : 0·89
	$7PbS.3Sb_2S_3 = Pb_7Sb_6S_{16}$ ...	53·96	26·92	19·12	1 : 0·86

[1] *Pogg. Ann.* XXVIII. 422. The two analyses were made on crystals from different specimens (Berzelius' *Jahresber.* 1835, XIV. 173; *Pogg Ann.* 1835, XXXV. 362).

[2] *Loc. cit.* (*a*) Mean of three analyses on selected crystalline material; (*b*) on massive material, after deducting 7 per cent. of blende.

[3] Rammelsberg's *Handwörterb. chem. Min.* 1847, 3rd Suppl., p. 44. This is the massive heteromorphite described by Zincken and Rammelsberg, *Pogg. Ann.* 1849, LXXVII. 240. Compare Rammelsberg's *Handb. Min.-chem.* 1860, p. 71, where different figures are given: a second analysis is given here, which agrees more closely with $2PbS.Sb_2S_3$.

[4] On crystals: Krenner (*loc. cit.*). A more detailed account of this analysis is given by Sipőcz in *Tscherm. Min. Mitth.* 1886, VII. 283.

Digitized by Google

In attempting to explain the relation between these minerals, three suggestions present themselves:

(1). That the crystals may enclose galena.

(2). That there may be isomorphous mixing of two end members, as in the plagioclase and scapolite groups.

(3). That the three minerals may be members of a morphotropic series, in which the vertical crystallographic axis increases in length with an increase in the amount of lead.

While examining and selecting material for the three analyses, the first suggestion was kept constantly in view, but no indications of the presence of galena could be found. Unless it were very finely disseminated, it would, on account of the lead-grey colour and perfect cleavage, be easily detected under a microscope fitted with accessories for illuminating opaque objects; further, all the British Museum specimens from Wolfsberg and Arnsberg were carefully examined, but no galena could be found on any of them; moreover, galena is not a mineral recorded from the antimony (stibnite) mines at Wolfsberg and Arnsberg. The semseyite from Felsőbánya (and Rodna), however, occurs as small crystals coating corroded galena, and in this case it would not be easy to collect material entirely free from galena. The presence of any galena might be detected by the action of suitable solvents; hydrochloric acid, however, would not do, since it decomposes both plagionite and galena. Also if the variation in composition were due to enclosed galena, there would then be no variation in the crystalline form, as is shown (but perhaps not absolutely proved) to be the case by Krenner's measurements.

The second suggestion is rather supported by the gradual variation in composition and by the absence of any simple formula, but it would not explain why the analyses fall into three fairly well-marked groups. The two unknown end members would presumably have more simple formulæ than the extremes given above, and they would probably show a wider variation in the parameter c than now shown. But the difference in the angles of the members already known is greater than is the rule in isomorphous substances, and certainly considerably greater than in the plagioclase and scapolite groups.

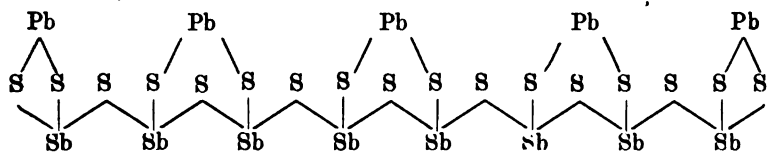
On the whole, the third suggestion, that of a morphotropic series, seems the most probable. Amongst minerals, the only morphotropic series yet established is that of the humite group[1]; it has also been

[1] *Min. Mag.* 1896, XI. 137, 161.

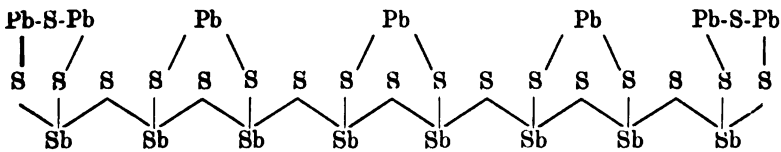
Digitized by Google

suggested that andorite, diaphorite and freieslebenite form such a series.[1] In both these cases the crystals of members of each group are so similar in appearance that they cannot be distinguished by mere inspection, and the only essential difference between them is in the greater length of the vertical axis, which varies regularly with the chemical composition, while the parameters $a : b$ remain practically constant. This is exactly the relation existing between plagionite and semseyite.

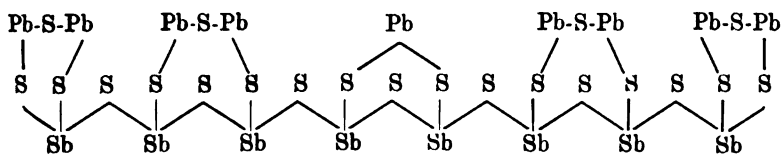
In these cases the comparison of structural formulæ is suggestive, and such formulæ have been given for chondrodite, humite and clinohumite by Sjögren and F. W. Clarke. The following structural formula for plagionite ($5PbS.4Sb_2S_3$) has recently been given by V. C. Butureanu[2]:



Replacing two of the —Pb— atoms by the groups —Pb—S—Pb—, the heteromorphite formula $7PbS.4Sb_2S_3$ is obtained:



Introducing four such groups, we get the formula $9PbS.4Sb_2S_3$, and this agrees better with the analysis of the original semseyite than does the formula $7PbS.3Sb_2S_3$ given by Krenner.



These formulæ are symmetrical, and the manner in which new atoms of lead are introduced suggests a relation with the increase in the vertical axis of the monosymmetric crystals. Two other possible formulæ in the same series are $8PbS.4Sb_2S_3 = 2PbS.Sb_2S_3$ and $10PbS.4Sb_2S_3$.

---

[1] L. J. Spencer, "Diaphorite from Washington and Mexico," *Amer. J. Sci.* 1898, VI. 316.

[2] *Bull. Soc. Sci.* Bucarest, 1897, VI. 179.

Digitized by Google

An objection to this is that only a few of the analyses agree exactly with the three formulæ, $5PbS.4Sb_2S_3$, $7PbS.4Sb_2S_3$ and $9PbS.4Sb_2S_3$, and, in fact, almost every analysis requires a different formula. Since isomorphous mixture has been provisionally rejected, another explanation must be given for this variation in composition.

The only crystals which have as yet given satisfactory measured angles are those of the extreme members with the formulæ $5PbS.4Sb_2S_3$ and $9PbS.4Sb_2S_3$. Other crystals are very imperfect, and opposite planes of the same form are never quite parallel; they appear, in fact, to be built up of smaller crystals whose crystallographic elements are not quite the same, so that the compound crystals, although having the same habit as the smaller crystals, are distorted and twisted. The smaller crystals may be supposed to have definite compositions, as given by the three formulæ above; the bulk analysis of a compound crystal would then give an indefinite formula, e.g. the formula $21PbS.10Sb_2S_3$ in section III. This is perhaps supported by the specific gravity determinations in sections I and III; in both cases the sp. gr. of the material analysed was slightly less than for the whole group. Pisani also found variations in the specific gravity.

It is possible that other twisted crystals may be explained in the same way: e.g. the saddle-shaped crystals of dolomite may be built up of smaller crystals containing different proportions of $CaCO_3$ and $MgCO_3$, and consequently with different crystal angles.

Besides the three localities mentioned above, viz. Wolfsberg, Arnsberg and Felsőbánya, plagionite-like minerals have been recorded from seven other localities; but as none of these have been properly determined, it is impossible to say whether they are plagionite, heteromorphite or semseyite.

Previous crystallographic determinations made on material not analysed now become of little value. The parameters given by me (*Min. Mag.* 1897, XI. 194) were calculated from the mean angles measured on the seven best crystals (from four specimens), and these, it is now seen, may have varied considerably in chemical composition. On these crystals the angle $c\,n = 001 : 111$ varied by 3°, and by more than 2° on one and the same crystal; the extreme means of the several readings for each crystal were 41°5′ – 41°45′. Although it still seems probable that these crystals were plagionite, and that the variations in the measured angles were due to the imperfections of the crystals rather than to differences in composition, it is nevertheless quite possible that some of the "new" forms (all determined on these seven crystals) may be reduced to forms already known when referred to the heteromorphite or semseyite axes.

Digitized by Google

Petrographical Notes on the Rock-specimens collected in Antarctic Regions during the voyage of H.M.S. Erebus and Terror under Sir James Clark Ross, in 1839-43.

By G. T. Prior, M.A., F.G.S.,

Assistant in the Mineral Department of the British Museum.

[Read Nov. 15th, 1898.]

Introduction.

THE rock-specimens collected during the Antarctic Expedition of 1839-43 were deposited in the British Museum. A few years ago, in the course of a re-arrangement and registration of the rock-specimens n the Museum, this collection amongst others was examined, and microscopic sections of some of the specimens were prepared. Nothing, however, was published at that time, since it was found that the greater part of the collection had been practically duplicated by the rocks of the *Challenger* Expedition, which had a year or two previously been deposited in the Museum, and it was felt that mere petrographical descriptions of specimens have but little to recommend them in the absence of geological data as to the mode of occurrence and mutual relations of the rocks in the field.

During the recent revival of interest in Antarctic exploration, however, inquiries were made regarding the rock-specimens collected by the Ross Expedition, and it was suggested by Sir John Murray that some petrographical description of them would at the present time be highly desirable. The following notes on the specimens collected in Antarctic regions have accordingly been prepared.

By far the greater part of the Ross collection consists of specimens from Kerguelen Land similar to those brought back by the *Challenger* Expedition. The latter have been fully investigated by Renard: the present paper is therefore confined to the description of the rocks collected in Antarctic regions during the three voyages southward made by the Expedition, starting from Tasmania, New Zealand, and the Falkland Islands respectively.

Digitized by Google

The Antarctic Expedition of 1839-43 was undertaken by the Government at the instigation originally of a Committee appointed by the British Association for the Advancement of Science at its eighth meeting, held at Newcastle in 1838. Its main object was to advance the Science of Terrestrial Magnetism by an extensive series of observations made in high southern latitudes. An account of the Expedition is given in *A Voyage of Discovery and Research in the Southern and Antarctic Regions during the years* 1839-43, by Sir James Clark Ross (London, John Murray, 1849); and also in *Voyages of Discovery in the Arctic and Antarctic Seas, &c.*, by Robert McCormick (London, Sampson, Low, 1884). McCormick was chief surgeon on board the *Erebus*, and was mainly responsible for the collection of the rock-specimens. In appendices to Ross's book he gives brief geological accounts of the various regions visited by the expedition; but unfortunately these so-called geological accounts in most cases resolve themselves into exasperating (from a petrological point of view) descriptions of birds, for the doctor appears to have been a more enthusiastic ornithologist than geologist.

The Expedition started from Chatham in September 1839, and after visiting Madeira, the Cape Verde Islands, St. Paul's Rocks, the little island of Trinidad off Brazil, and St. Helena, at all of which places magnetic observations were made and a few rock-specimens collected, arrived at the Cape of Good Hope in March 1840. Thence it proceeded to Kerguelen Land, and after spending two months on that desolate island, reached Tasmania in August. Here the Expedition remained until November, when a start was made on a voyage into Antarctic regions.

I. First Voyage Southward.

In the first voyage southward, the first land visited by the Expedition after leaving Hobart Town was the Auckland Islands.

(1.) *Auckland Islands.*

These islands, discovered in 1806 by Captain Bristow, are situated about 300 miles south of New Zealand, in about lat. 50° 32′ S. and long. 166° 12′ E.

According to McCormick they are volcanic, being constituted chiefly of basalt, which at Dea's Head, a promontory of Auckland Island, forms fine columns. These islands were used in 1874 by the German astronomers as the station for the observation of the transit of Venus. According to Hermann Krone, a member of this Expedition, the largest of the islands has an area of seven square miles; all of them are volcanic, and

Digitized by Google

consist of an older trachyte[1] formation succeeded by basalt; the highest hill, Mount Eden, is 404 metres high, and is crowned with a mass of basalt. A few rolled pebbles of basalt collected by Dr. Seeliger, another member of this expedition, have been described[2] by Max Hartmann. They were all felspar-basalts, mostly of coarse-grained doleritic structure; in one of the specimens the presence of nepheline is doubtfully recorded.

All the specimens from the Auckland Islands collected by the Ross Expedition are also of *felspar-basalt*, but of a fine-grained porphyritic rather than of doleritic type. Most of them consist of flat slabs (with brown weathered surfaces) of a bluish-grey fine-grained rock, showing large (up to 1 cm. in length) porphyritic crystals of black augite, and of perfectly fresh and transparent yellow olivine. Under the microscope, phenocrysts of pale purplish titaniferous augite and, in less amount, of olivine with a few labradorites are seen distributed in a fine-grained groundmass of felspar laths showing flow structure, magnetite, and pale green to purple granular augite. In one specimen the groundmass also contained small olivines.

The augite phenocrysts in some specimens have definite crystal outlines, and show octagonal sections bounded by prism and pinacoid faces, but in others they have been corroded and penetrated by the magma, and have rounded contours with a margin of alteration crowded with grains of magnetite. The pleochroism in basal sections was from purplish brown to yellowish brown; the extinction on cleavage flakes was nearly 40°; polysynthetic twinning on $a(100)$ was noted in several sections, and also hour-glass structure. Inclusions of magnetite and of groundmass were common; in one section very minute black needles arranged in two parallel sets inclined at an angle of about 60° were observed.

The olivine phenocrysts have slightly rounded outlines, and are very clear and fresh. Between crossed nicols inclusions can be seen in some sections of very minute star-like radiating groups of a strongly doubly refracting mineral. They remind one of the gypsum crystals obtained in microchemical reactions, and are thus very similar to the sahlite needles in the altered olivine of the Medenbach picrite recently described and figured by R. Brauns.[3] In the present case, however, from their small angle of extinction, I am inclined to refer them to tremolite. I have

[1] No specimens of this trachyte appear to have been collected by this German expedition, nor was one found in the Ross collection. Some uncertainty must therefore exist as to the nature of this older formation.

[2] *Neues Jahrb. f. Min. u. Petr.* 1878, pp. 825–30.

[3] *Neues Jahrb. f. Min. u. Petr.* 1898 (2), 179.

Digitized by Google

noted similar minute inclusions in the olivine of nepheline-basalts from Fernando Noronha.

The porphyritic felspars are small prismatic, and often occur in patches of several individuals. They show broad albite twin-lamination with symmetrical extinction of about 30°, so that they may be referred to labradorite; a few crystals, however, with zonal extinction appear to be of a more acid type.

The specific gravity of this rock was 2·85.

In general character the basalt approximates closely to some of the Bohemian felspar-basalts described by Boricky.

Another specimen less distinctly porphyritic, and apparently of more basic type than the preceding, was of a dark grey colour, and showed to the naked eye only small porphyritic olivines. Under the microscope it presents somewhat similar characters to those of the last rock, but the olivine phenocrysts are in far larger amount, and show along cracks and round the margin a green alteration product. The pale purple augite occurs generally in groups of several individuals, often in association with the olivine; in one case a large olivine crystal is completely surrounded by a border of augite grains. The felspar phenocrysts are in subordinate amount, and show all stages of absorption by the base. They are rounded and corroded, often into the most fantastic shapes; in some cases the groundmass has penetrated into them along definite channels, in other cases its constituents, magnetite and augite microliths, pervade them in such a way that they lose all definite outline.

Of a somewhat different type is a rock labelled "Oceanic Point." It is a dark grey basalt, not markedly porphyritic, but showing to the lens on the rough weathered surface small yellow olivines. Under the microscope the only phenocrysts are seen to be of olivine. These are small and clear, but are generally rounded, and are often penetrated by and include portions of the groundmass. This groundmass consists of lath-shaped crystals of labradorite (symmetrical extinction of about 25°), with much pale green to colourless granular augite and iron ores. The latter (in part probably ilmenite) is in rod-like skeleton crystals, generally wedged between the felspar-laths and obviously one of the last minerals to consolidate; in the neighbourhood of the olivine phenocrysts in some cases the rods (or plates) are arranged at right angles to the axis of the olivine, as observed by Reusch in basalts from Jan Mayen[1] and by Streng

[1] *Neues Jahrb. f. Min. u. Petr.* 1883 (2), 224.

Digitized by Google

in the Londorf dolerite.[1] This directional character is particularly marked in the case of patches of groundmass included in the olivines.

A specimen labelled "Pig Island" is a black compact basalt consisting of a very fine-grained felt of felspar laths, pale green augite microliths and much granular magnetite. Olivine occurs very sparingly in small grains, and a deep purple augite in minute prismatic crystals.

Finally, from Dea's Head is a basalt of a somewhat coarser-grained type than any of the preceding. It is a dark grey, slightly vesicular rock, showing to the lens small yellow olivines. These, under the microscope, are seen to occur in small idiomorphic crystals, some giving the usual hexagonal outlines, but others long prismatic and rod-shaped. All have a deep orange-red alteration product round the margin. Purple augite in prismatic crystals of varying size and often forming radiating groups is present in large amount, and is idiomorphic with respect to the small lath-shaped felspars which in subordinate amount form as it were the paste for the other constituents. Magnetite occurs in fairly large grains. One large irregular plate of ilmenite (?) enclosed crystals of felspar and purple augite.

(2.) *Campbell Island.*

Campbell Island, the next land touched by the Expedition, is about 120 miles S.W. of the Auckland Islands, in lat. 52° 33′ S. and long. 169° 8′ E. Hazelburgh, who discovered the island in 1810, states that it is 30 miles in circumference, and is mountainous. The hills, of which the highest has an elevation of 1,500 ft., were less wooded than those of the Auckland Islands.

According to McCormick, the geology of the island is very similar to that of the Aucklands. Pebbles of quartz and agate, however, and traces of limestone were found amongst the shingle on the beach, "the only indication of the sedimentary class of rocks which we met with after our departure from the Australian lands."

The specimens from Campbell Island consist of *basalt*, *silicified foraminiferal limestone*, and *chert*.

One large specimen of compact dark bluish gray porphyritic basalt presents both macroscopically and under the microscope almost precisely the same characters as those of the basalt from the Auckland Islands described on p. 71.

Another basalt specimen is very vesicular and of a coarser-grained type. Under the microscope crystals of purplish augite, altered olivines

[1] *Neues Jahrb. f. Min. u. Petr*, 1888 (2), 181.

Digitized by Google

with hexagonal sections and prismatic felspars, are seen in a medium-grained base of granular purple augite, felspar laths and skeleton growths of magnetite. The olivine and felspar are almost wholly converted into a green alteration product, while the purple augite remains perfectly fresh.

Of the sedimentary rocks referred to by McCormick there are three specimens. One of them is a small fragment of hard compact siliceous limestone labelled "Lime from a vein in basalt, South Harbour, Campbell's Island." A thin section shows that it consists largely of the remains of foraminifera (globigerina) in fairly good preservation. Treated with acid it effervesces strongly, but leaves a large siliceous residue. A partial quantitative analysis made on 0·7640 gram of this rock gave the following result:—

SiO_2 ...	...	=57·46
$CaCO_3$	...	=39·26
$MgCO_3$	...	= 0·36
$Al_2O_3(+Fe_2O_3)$		= 1·48
H_2O, &c.	...	=(1·44)
		100·00

The specific gravity of the fragment was as low as 2·15.

To the kindness of Messrs. H. W. Burrows and R. Holland I am indebted for the following note, in which are enumerated the species of foraminifera identified by them in sections cut from this specimen:—

"This is a compacted *Globigerina* ooze of essentially modern character, certainly, in our opinion, not older than Post Pliocene.

"It is closely matched by the deposits now accumulating at other parts of the S. Pacific, and is very like some of the soundings in our own collection, notably those off Molyneux, and off Otago, New Zealand.[1]

"The *Foraminifera* are in a very fresh condition, and in this respect resemble those in a palagonite-tuff in Mr. C. W. Andrews' collection from Christmas Island.

"We have determined the following species in the two slides—

"v.r. *Pulvinulina Micheliniana*, d'Orb.

"v.c. *Globigerina bulloides*, d'Orb., spinose.

"v.c. *Globigerina bulloides*, var. *triloba*, Rss., spinose.

[1] The precise localities referred to are—Off E. of Otago, 953 faths. lat. 45°55′ S.; 72°46′8″ E. Off Molyneux, 614 faths. lat. 46°37′ S.; long. 171°2′7″ E.

Digitized by Google

"v.c. *Orbulina universa*, d'Orb.
"r. *Bulimina affinis*, d'Orb.
"r. *Bolivina* sp.

"The species are, doubtless, more numerous, as we notice fragments which are not referable to the above-named species, but they are not sufficiently distinct to be determinable."

The other two specimens are of chert, probably representing the final stages of the silicification of the limestone. One of them, of flinty hornstone-like appearance, shows under the microscope remains of globigerina, but in a far less perfect state of preservation than in the preceding specimen.

The third specimen has a more felsitic appearance, and is covered with small quartz crystals. No organisms can be definitely distinguished under the microscope.

(8.) *Possession Island.*

After leaving Campbell Island, the Expedition crossed the Antarctic Circle, and soon after became beset in the pack ice. Having passed through the pack, it emerged into an open sea, and, proceeding further southward, on January 11th, 1841, in about lat. 71° S. and long. 171° E., discovered Victoria Land, "rising steeply from the ocean," as described by McCormick, "in a stupendous mountain range, peak above peak, enveloped in perpetual snow." Some of these peaks attain an altitude of from 10,000 to 15,000 feet. From the dark colour of the rocks, where they broke through their icy covering, and from several black pebbles dredged up off the northern promontory, Cape Adare, Ross formed the opinion that the newly-discovered land was of volcanic origin.[1] The mainland could not be approached, but a landing was effected on a small island (Possession Island) lying off it in about lat. 71° 56′ S. and long. 171° 7′ E.

According to McCormick this island is composed of "volcanic conglomerate, vesicular lava, and basalt," rising to a height of about 300 feet. It showed not the smallest vestige of vegetation. McCormick describes the fantastic shapes assumed by the basaltic rocks, and mentions a cave showing fine columns, "a Fingal's cave in miniature."

The specimens labelled as from Possession Island include *basalts palagonite-tuff*, *phonolite* and fragments of *muscovite-granite*.

---

[1] According to Sir John Murray (*Proc. Roy. Soc.* 1898, LXII. p. 424) Borchgrevink and Bull have recently brought back fragments of mica-schist from Cape Adare. A nepheline-tephrite from the same locality has been described by Teall.

Digitized by Google

Basalts.

A scoriaceous black basalt, in which no porphyritic crystals could be distinguished with the naked eye, was seen under the microscope to consist of a very fine-grained dense almost opaque felt of magnetite grains, felspar laths, and minute colourless augite microliths, with here and there, very sparingly, rhombic sections of olivine showing generally a central inclusion of glass. The larger felspar laths, on one of which a symmetrical extinction angle about the twin lamellæ of 25° was measured (labradorite), marked the flow-structure of the rock. Small phenocrysts of a pale purple augite, showing inclusions of magnetite and olivine, occur sparingly.

An interesting feature is the presence of a few small phenocrysts of a deep brown basaltic hornblende. Some of these, in process of absorption by the base, are lenticular in shape, and are surrounded by a zone of magnetite grains. In one case this hornblende forms a zone round an irregular fragment of augite, as though of later date.[1]

In the hand-specimen a fragment of this hornblende, about 2 mm. cube, occurs loosely attached in a cavity, as if it had been caught up in the lava flow. Cleavage flakes from this fragment are only transparent when very thin, give almost straight extinction, and in convergent light show signs of both axial brushes, so that an optic axis is not very near the centre of the field as it is in the case of ordinary hornblende. The pleochroism was, in a cleavage flake, light yellow-brown to deep brown (almost black); in a section showing both cleavages, light yellow-brown for *a* and deep reddish-brown for *b*. The cleavage angle measured on the reflecting goniometer was 124° 34′.

A rolled pebble of compact black basalt, showing to the lens only a few minute phenocrysts of augite, presents under the microscope somewhat similar characters to those of the preceding rock, but is of coarser grain. The only phenocrysts are of a pale purple augite (generally with a green centre). Most of the sections have well-defined rectangular or octagonal crystal outlines, but some are corroded and surrounded by a zone of magnetite grains, and some show hour-glass structure. They generally enclose magnetite, and in some cases grains of olivine. In this specimen the hornblende has been wholly absorbed; many pseudomorphs, however, of the crystals are left as patches of densely crowded magnetite

[1] Since writing the above description, I find that Mr. Teall has recently examined and described some specimens of basalt from Possession Island brought back by Captain Jenssen. Sections kindly shown to me by Mr. Teall present precisely the same characters as those described above.

Digitized by Google

grains, sometimes lenticular in shape, but occasionally presenting crystal outlines. Some of these patches are surrounded by a narrow border of purplish augite; others have clearer spaces in the centre filled with an aggregate of magnetite, purple augite, and felspar, more coarsely crystallised than the groundmass. Consideration of this specimen and of the preceding suggests that it was only in the quickly cooled surface of the lava that the hornblende crystals have been preserved. In the more slowly cooled material they have been almost wholly absorbed by the groundmass.

The groundmass consists of magnetite and felspar laths, with olivine, a little augite, and traces of glass. The felspar and olivine have the same characters as in the preceding rock: the granular augite is in very small amount. The magnetite occurs in two generations, in grains and octahedra (in which form it is enclosed in the augite phenocrysts), and in minute rod-like skeleton growths fringing and often set at right angles to the sides of the felspar laths, and certainly one of the last minerals to separate. The specific gravity of this rock was 2·82.

These basalts are very similar to the hornblende-basalts in the Rhöngebirge, *e.g.* to the rock from Kirschberg, near Rasdorf, a specimen of which is in the Museum collection.

Another rolled pebble of black compact basalt is similar to the preceding, but is finer grained, and contains no porphyritic crystals. It consists of a fine grained felt of felspar laths, a little granular augite and olivine, with much magnetite in grains and some purplish-brown glass. It is worthy of note that in this specimen containing glass there are no magnetite skeletons.

In the section are a few grains of quartz; these have probably been derived from the granite to be later described; they are surrounded by zones of pale greenish radiating needles, from their high angle of extinction (about 30°) referred to augite.

Adhering to this specimen was a piece of brown tuff containing, besides fragments of glassy basalt, also broken crystals of basaltic hornblende similar to that described above, and rounded grains of quartz.

Palagonite-Tuff.

A section of a pale brown palagonite-tuff, similar to that adhering to the basalt, showed fragments of highly vesicular basalt-glass, and of less glassy basalts similar to those described above, cemented by yellow palagonite and zeolites. Crystals of basaltic hornblende, quartz and felspar, and a fragment of the phonolite described below, also occurred.

Digitized by Google

The felspar was tabular, showing twin striations with symmetrical extinction of 6° (oligoclase). The quartz showed liquid inclusions with spontaneously moving bubbles, thus suggesting its deep-seated origin.

The very vesicular basalt-glass is light brown and fairly transparent. It contains comparatively large grains and crystals of magnetite, and lath-shaped felspars marking flow structure, with minute microliths of olivine, hornblende, and a little augite. Beside the lath-shaped crystals of felspar there are also extremely thin rhombic plates of a more acid felspar. The hornblende occurs in long prismatic microliths and also in perfectly rounded blebs. It is strongly pleochroic, and similar to that described above. The olivine occurs sparingly in minute rhombic sections, but mainly in forked skeleton crystals as figured in Rosenbusch's *Mikrosk. Physiog.* 2nd Ed. Vol. I. Plate II. Fig. 4. Often two of these skeleton crystals are crossed apparently in twin position. The augite in very minute long prismatic microliths, showing terminal faces and giving wide angles of extinction, is very sparingly present.

Some of the basalt fragments in the tuff were less glassy than the above. In these the magnetite had separated to a large extent in skeleton crystals: they also contained hornblende crystals and small rhombic sections of olivine.

Phonolite.

The specimen of phonolite from Possession Island is a compact brownish grey somewhat altered rock, showing to the naked eye only a few small porphyritic crystals of glassy felspar. Under the microscope it is seen to consist of a felt of felspar laths, a little magnetite, and ægyrine-augite uniformly distributed in small prismatic crystals and occasionally in granular aggregates. The maximum extinction in these prismatic crystals of ægyrine-augite was about 34°. An octagonal section showed a nearly rectangular cleavage, and in convergent light the emergence of an optic axis just off the field. The pleochroism in this section was from green to reddish-brown, while in a prismatic section it was green to brownish-green. These characters correspond to the ægyrine-augite of Rosenbusch, with axis a inclined 34° to c, and with pleochroism a=green, b=brownish-green, c=reddish-brown. The felspar laths give almost straight extinction; they show a general tendency to point in one direction, but sometimes form radiating groups. The structure is trachytic.

The presence of nepheline was only doubtfully indicated by a few rectangular sections with weak double refraction. A few minute grains of a strongly doubly refractive mineral are doubtfully referred to sphene.

Digitized by Google

Granite.

The fragments of muscovite-granite were probably derived from the tuff, since one of them had a little of the tuff adhering to one side of it. The granite consists of a medium-grained aggregate of quartz, microcline, orthoclase, oligoclase, and muscovite, with small black prismatic crystals of tourmaline. The quartz is the most plentiful constituent. It contains dusty inclusions, and also very minute liquid inclusions with spontaneously moving bubbles, as in the fragment included in the basalt. The felspars are quite fresh. The microcline is the most abundant. It appears to have been, as is generally the case in granites, the last mineral to consolidate, for it moulds the quartz which is generally rounded in contact with it, and it includes rounded grains both of quartz and oligoclase: a rounded quartz grain in contact with microcline appears to have been corroded and penetrated by the latter. The cross-hatching of the microcline is well shown between crossed nicols. The oligoclase shows very fine twin laminæ, and gives low angles of extinction. The muscovite occurs in large ragged plates. The tourmaline is in prismatic crystals enclosed in the quartz and microcline. In the quartz it occurs in all gradations of size down to the finest hairs. The pleochroism is from deep indigo-blue to pale lavender, but the larger crystals have a border with different pleochroism from brownish-yellow to pale lavender.

Some of the fragments of muscovite-granite contained, in addition to the tourmaline, small pink garnets.

(4.) *Franklin Island.*

After leaving Possession Island, the expedition proceeded along the coast of Victoria Land, with its "magnificent chain of mountains" stretching away to the southward, as described in Ross's account. A lofty peak named Mount Melbourne was, according to McCormick, evidently a volcanic cone, with a perfectly shaped crater.

When in about lat. 73° S. the dredge brought up a "block of grey granite, composed of large crystals of quartz, mica and felspar, with apparently a clean and recent fracture, as if lately broken off from the main rock." This specimen was not found in the collection.

Franklin Island, the most southerly land on which a landing was effected, is situated in lat. 76° 8′ S. and long. 168° 12′ E. and is about 12 miles long and 6 miles broad. According to Ross, it is composed wholly of igneous rocks. Not a trace of vegetation was found upon it.

The specimens collected are all of *basalt* of the same type.

It is a black compact rock, not markedly porphyritic. Under the microscope small idiomorphic olivines and magnetite are seen very

Digitized by Google

uniformly distributed in a base of purplish to colourless augite in minute prismatic microliths, and felspar in laths and in plates. In the base in subordinate amount were patches of a weakly doubly refractive mineral, which appeared to form a paste for the lath-shaped felspars. This is doubtfully referred to nepheline, since it gave straight extinction along straight edges, and in one section, which remained dark between crossed nicols, a faintly distinguishable uniaxial figure.

The olivine is in sharp hexagonal sections, generally bordered with a deep orange-red alteration product.

The augite of the groundmass is in minute prisms idiomorphic with respect to the felspar.

The felspar laths give nearly straight extinction, and are probably to be referred to andesine.

The specific gravity of the rock was 2·87.

The result of a quantitative chemical analysis is as follows :—

SiO_2	...	=	45·61
TiO_2	...	=	3·48
SnO_2	...	=	trace
Al_2O_3	...	=	15·70
Fe_2O_3	...	=	6·17
FeO	...	=	7·29
MnO	...	=	trace
CaO	...	=	6·34
MgO	...	=	4·84
K_2O	...	=	2·67
Na_2O	...	=	5·06
Loss on ignition		=	2·34
			99·50

In this analysis 1·4817 gram was used for the determination of silica, &c., by fusion with sodium and potassium carbonate; 0·6968 gram for the determination of ferrous oxide by decomposing with hydrofluoric and sulphuric acids in an atmosphere of carbonic acid, and titrating with permanganate of potash; and 0·6401 gram for the determination of alkalies by Lawrence Smith's method.

Proceeding southward from Franklin Island, the Expedition discovered in about lat. 77° 31′ S. and long. 167° 1′ E. the active volcano discharging "flame and smoke," Mount Erebus, 12,367 feet in height, with the neighbouring extinct crater, Mount Terror, 10,884 feet high.

From the cape at the foot of these mountains extended to the eastward

Digitized by Google

that vast barrier of ice forming a continuous perpendicular wall, varying in height from 100 to 200 feet, which prevented all further progress southward. Along the face of this great wall of ice the Expedition sailed for about 300 miles without finding any inlet. According to Sir John Murray (*Proc. Roy. Soc.* LXII. No. 387, pp. 424-51) this great ice barrier "was evidently the sea-front of a great creeping glacier or ice-cap, just then in the condition to give birth to the table-shaped icebergs, miles in length, which have been described by every Antarctic voyager." The proximity of this ice-barrier to extended land surfaces thus suggested receives some sort of confirmation from the fact mentioned by Ross, that in soundings made off the barrier in 410 fathoms in about lat. 77° 47′ S. and long. 176° 43′ E. the leads sank fully two feet into a soft green mud; for during the voyage of the *Challenger* the dredging up of blue and green muds, derived from the degradation of crystalline rocks, was always a sure indication of the approach to land. Unfortunately no specimen of this green mud appears to have been preserved.

II. Second Voyage Southward.

On the second journey southward the expedition was beset for long periods in the pack ice, and no landing was effected anywhere.

The only rock specimens collected were in the form of pebbles found in the stomachs of seals and penguins.

These specimens are of interest as throwing some light upon the question as to the existence and character of that great Antarctic continent which is supposed to encircle the South Pole, for in all probability they were obtained by the seals and penguins from floating ice which at one time helped to form the glaciers of that southern land. The fact that blocks of gneiss and granite,[1] which must have been deposited from icebergs, were dredged up by the *Challenger* Expedition in southern latitudes, is brought forward as evidence of the existence of this continent. The evidence afforded by these pebbles is of a similar character, as will be seen from the following descriptions. The effects of dynamic metamorphism observed in many of them also indicate that the region from which they came has been the seat of great mechanical disturbances. Amongst the pebbles are examples of the following kinds of rock :—

[1] In the Museum is exhibited a large block of gneiss dredged from diatom-ooze, in lat. 53° 55′ S. and long. 108° 35′ E., about 600 miles N.E. of Wilkes Termination Land. According to Sir John Murray (*Proc. Roy. Soc.* 1898, LXII. pp. 424—51), the dredgings of the *Challenger* brought up, besides gneiss and granite, also mica-schists, diorites, quartzites, sandstones, limestones and shales.

Digitized by Google

From a seal caught Dec. 1841, in about lat. 63° 4′ S. and long. 151° 2′ W.: *granite* and *epidiorite*.

From a large penguin caught Dec. 22, 1841, in lat. 65° S. and long. 154° W.: *granite*, *basalt* and *rhyolitic breccia*.

From a seal caught Jan. 1842, in about lat. 66° S. and long. 156° W.: *granite*, *epidiorite*, *dolerite*, *basalt* and *rhyolite*.

From a penguin caught Jan. 28th, 1842, in about lat. 67° S. and long. 156° W.: *micaceous quartz-grit* (*micaceous schists*).

Granites.

The granites are pink and grey rocks, consisting of quartz, orthoclase, oligoclase, and a little biotite and hornblende. Most of them show to a greater or less extent the effects attributed to dynamic metamorphism. The quartz almost invariably shows marked undulose extinction, and each grain between crossed nicols resolves itself into an aggregate of irregular differently orientated smaller grains. It contains strings of dusty inclusions and fluid-pores with spontaneously moving bubbles.

The oligoclase shows thin twin laminæ which are often bent. In some specimens it is altered with development of much clear yellow epidote.

The biotite is generally only present in small amount: in some specimens it has been converted into pleochroic chlorite.

The orthoclase in some of the pebbles appears to have been largely replaced by microcline. The cross-hatching, however, is not well marked, and it is possible that we have here an example of microcline structure developed in orthoclase as the result of mechanical strain.

In some of the granites the effects of earth stresses are even more marked, and advanced stages of cataclastic structure precisely similar to those figured in Rosenbusch's *Mikros. Physiog.* Vol. II. Plate I. Figs. 3 and 4, are exhibited.

One pebble showed the contact of such a cataclastic granite with an epidiorite which is probably a dolerite metamorphosed by the same dynamic effects which have affected the granite.

Epidiorites.

The epidiorites are dark green rocks, presenting generally very similar characters to those of the well-known rock of the Scourie dyke described by Teall.[1] They are probably metamorphosed dykes of dolerite in granite, for several of the pebbles show the contact of epidiorite and granite. Under the microscope one specimen shows green hornblende in small

[1] *British Petrography*, Pl. XIX, XX, pp. 197–200.

Digitized by Google

ragged grains, often aggregated into groups, but generally fairly uniformly distributed in a paste of water-clear felspar, which is partly in laths with indistinct outline and partly in plates.

The felspar has the characters attributed to secondary felspar. It is water-clear, and for the most part shows no twin striations, so that it is often only to be distinguished from quartz by observation in convergent light. The lath-shaped crystals have nearly straight extinction, and are probably andesine. One or two larger sections showing twin striations are more basic, and are probably some of the original labradorite of the dolerite. One section, giving symmetrical extinction of about 28°, had a border of water-clear felspar, giving straight extinction. The hornblende is similar to that of the Scourie dyke, but does not occur in such large plates. The pleochroism was a = pale yellow, b = dull yellowish-green, c = dull bluish-green.

Magnetite is present in comparatively large grains, but in small amount. Calcite and epidote occur in minute veins.

Finally, there are one or two irregular patches of a yellow mineral, which from its very strong refraction and double refraction was referred to sphene. This was confirmed by observation of one section, which showed in convergent light a positive biaxial figure with a small optic axial angle and with strong dispersion $\rho > v$.

In the specimen showing the contact of epidiorite and cataclastic granite, this granular sphene with a little hornblende is seen to occur near the contact both in the granite and in the epidiorite. As in the case of the Scourie-dyke rock, the sphene has probably resulted from the alteration of the titaniferous iron-ore of the original dolerite.

Other specimens showed less advanced stages of alteration, and except for the change of augite to hornblende were nearer to ordinary dolerites. One example consisted of small lath-shaped felspars showing flow structure, with large irregular ragged patches of a fibrous hornblende showing pleochroism a = very pale yellow, b = pale dirty greenish-brown, c = dirty bluish-green. Biotite is present in small amount, and magnetite in comparatively large grains.

Another specimen was coarser-grained, and showed large prismatic felspars, a little quartz and large ragged patches of biotite and hornblende. The hornblende had obviously resulted from the alteration of augite, since the latter mineral occurs as the nucleus of one or two of the hornblende patches.

Dolerites.

The dolerites found among the pebbles were somewhat similar in

Digitized by Google

character to the unaltered dolerite of the Scourie dyke, and might well have been the original rocks from which some of the above epidiorites were derived.

One example consists of a coarse-grained aggregate of broad prismatic crystals of labradorite (symmetrical extinction of about 25°) and pale purple augite in irregular plates, penetrated by the felspar, and thus presenting a sub-ophitic structure. Iron-ore, probably titaniferous, occurs in irregular plates. Yellow fibrous hornblende is present in small amount, probably resulting from the alteration of the augite. In the section is a small patch of kaolinised felspar (in tabular crystals and of more acid type) which appears to be a foreign inclusion, probably from a granite.

Another specimen is of similar character to the preceding, but of much coarser grain. It consists of large interlacing prismatic crystals of labradorite with broad ophitic patches of greenish-brown fibrous hornblende, containing in many cases a nucleus of the original purple augite. Iron ore was present as in the preceding rock.

Basalts.

Amongst the basalts no specimen precisely similar to any of those described in the first section of this paper was found. This should not be surprising if the supposition is well grounded that the pebbles were mainly derived from a great Antarctic continent further southward. One specimen, however, bore some resemblance to basalts from Cockburn Island, off Louis Philippe Land, to be described in the next section.

In this rock the only porphyritic constituent is perfectly clear fresh olivine in large crystals, generally with fairly sharp hexagonal outlines, but sometimes invaded by the base. They contain a few inclusions of magnetite, picotite (?), and blebs of glass. The groundmass consists of very minute microliths and forked skeleton crystals of felspar in a deep brown glass crowded with minute skeleton growths of magnetite. Augite in small amount is only to be distinguished between the felspars and intergrown with magnetite by the polarisation colours. As in the Cockburn basalts (see p. 87), this mineral and the magnetite appear to have been the last to separate. In the groundmass were also a few small grains of olivine; sometimes two such grains would be attached on each side of a felspar lath, as though of later date. Scattered through the base were numerous minute round colourless isotropic patches, looking like microscopic vesicles filled with an isotropic zeolite.

Another basalt, medium-grained approaching to dolerite, shows microporphyritic lath-shaped felspars and altered olivine in a base of smaller

Digitized by Google

felspar laths, altered olivine and purple augite minutely ophitic with respect to the felspar. Magnetite is present in comparatively large crystals and rods. The larger felspars are of labradorite with a symmetrical extinction angle about twin laminæ of 29°, and are of the same general character as the smaller ones of the base. Symmetrical extinction angles, however, in the latter were generally lower (19°). The olivine is in large amount, but is all altered to a yellowish-brown fibrous strongly doubly refractive hornblendic (?) mineral.

Another basalt specimen is of more acid type. It consists of a few porphyritic labradorites (symmetrical extinction of about 21°) in prismatic crystals much corroded and partially re-absorbed by the base, with a few small purplish augites, in a dense base containing much granular magnetite, colourless augite in grains and minute prisms, and lath-shaped felspars giving straight extinction (probably andesine).

Rhyolites.

One specimen appears to be a rhyolitic breccia. It consists of much altered fragments of microfelsitic material, probably a devitrified glass, showing flow structure, and containing corroded quartz grains penetrated by the magma.

Another much altered specimen shows under the microscope alternating parts of clear and cloudy cryptocrystalline material. The cloudy material appears to consist of pseudo-spherulites. Between crossed nicols the section resolves itself into an aggregate of round patches of differently orientated material, but no definite black crosses are seen. One or two corroded quartz grains occur as the nuclei of some of the circular patches. Some of the Hungarian rhyolites present a similar structure, *e.g.* the rock from Abanj Szanto, Tokaj.

Micaceous Quartz-Grits (micaceous schists).

One specimen shows sub-angular quartz grains with brown interstitial matter containing smaller quartz grains and ill-defined biotite. The quartz contains liquid inclusions with spontaneously moving bubbles. In the arrangement of the quartz grains there is some approach to schistose structure.

Another specimen consists of clear quartz grains connected by a network of apparently more recent quartz, with lines of reddish-brown pleochroic biotite giving foliated structure.

The microscopic characters of these specimens suggest the idea that they may be quartz-grits metamorphosed by granite-contact into micaceous schists.

Digitized by Google

III. Third Voyage Southward.

In the course of the third voyage into Antarctic regions, the only landing effected was on Cockburn Island, in lat. 64° 12′ S. and long. 56° 49′ W., off Louis Philippe Land, south of the South Shetlands.

About this particular part of the Antarctic regions, according to Sir Archibald Geikie,[1] within recent years sealing vessels have brought home scraps of information. Thus from the islets of Graham Land to the south of the South Shetlands fragments of granite, volcanic rocks and fossiliferous limestone have been collected. From Dundee Island, close to Joinville Island which forms the north-eastern termination of Graham Land, come specimens of granite[2] and a piece of radiolarian chert very similar to cherts in the Lower Silurian formations of the United Kingdom. From Seymour Island, in the same district, Captain Larsen brought back pieces of fossil coniferous wood, and also fossil shells similar to species in lower Tertiary beds of Patagonia.

The specimens from Cockburn Island collected by the Ross Expedition include *basalt*, *palagonite-tuff*, *granite*, and *calcareous glauconitic sandstone*.

Basalts.

The basalt specimens are of a black compact, generally non-vesicular rock, showing to the naked eye porphyritic perfectly fresh yellow olivines, while with the lens small striated lath-shaped felspars can be detected. One large specimen shows the ropy surface of the lava consisting to the depth of more than half an inch of basalt-glass. All the specimens probably came from the same eruptive mass, but they show under the microscope interesting gradations of structure from a clear glass to a perfectly crystalline rock.

The most holocrystalline rock of this series consists of a medium-grained aggregate of olivine, felspar laths, deep purple augite and magnetite. The olivines occur in two generations, in large phenocrysts and in smaller crystals between the felspar laths. The augite is in small irregular ophitic patches penetrated by the felspars.

In other specimens the structure is more distinctly porphyritic: phenocrysts of clear unaltered olivine occur in a medium-grained base of lath-shaped felspars, the interstices between which are filled with augite intergrown with skeleton crystals of magnetite. The colour of the augite varies from deep purple to almost colourless.

---

[1] *Proc. Roy. Soc.* 1898, LXII, pp. 424–51, and *Proc. Roy. Soc. Edinb.* 1898, XXII, p. 66.

[2] ribed by Teall (*Proc. Roy. Soc. Edinb.* XXII. (1898), p. 58).

Digitized by Google

In other specimens the interstitial augite is more indistinct and more confusedly intergrown with magnetite, so that it can often only be recognised by the colours between crossed nicols.

In yet other specimens the magnetite skeletons are very minute and feathery, and no augite can be distinguished. In these specimens the same orientation as previously described of the magnetite rods at right angles to the olivine and to the length of the felspar laths was noted.

Then there are specimens in which the interstices between the felspar laths are filled with a deep brown glass, with only slight separation of magnetite.

Finally, on the surface of the lava-flow is a clear light-brown glass, with phenocrysts of olivine and felspar and no separation of magnetite whatever.

Such a concentration of iron in the mother-liquor of basic magmas as indicated by the above observations has been recently noted and emphasised by Teall in the case of basalts from Franz Josef Land.[1]

The olivine in all the above specimens is of the same character. It is generally perfectly clear and fresh. The large phenocrysts show mostly sharply-defined hexagonal sections, but sometimes occur in groups of broken fragments separated by the magma. Occasionally they are in elongated prismatic crystals, as described by Dana in the case of Hawaiian basalts.[2] In many cases they have been corroded and penetrated by the magma. They contain inclusions of brown sub-translucent octahedra of picotite (?) and of glass (showing sometimes separation of augite and magnetite).

The olivine of the groundmass is in large amount and shows rhombic sections with central inclusions of glass. It sometimes occurs included in the felspars, but is often in irregular patches interpenetrated by the felspar laths, as if of later consolidation.

The felspar in these specimens is mainly a basic labradorite with twin striations showing a maximum symmetrical extinction of about 32°. Besides these sharply defined lath-shaped felspars, in some specimens there are a few larger and broader felspars of a more acid type having zonal extinction. These are often cracked and bent, and show rounded indistinct outlines as if partially absorbed. One section, showing no twin lamine, exhibited in convergent light a positive biaxial figure with a very small optic axial angle.

---

[1] *Quart. Journ. Geol. Soc.* LIII, (1897), p. 487.

[2] *Am. Journ. Sci.* XXXVII. (1889). p. 441.

Digitized by Google

Magnetite occurs generally in skeleton growths as one of the last minerals to separate: only in the holocrystalline specimen, in which the augite is in ophitic patches, does it occur in large grains, and in this case these grains appear to be generally wedged in between the felspar laths.

Basalt Glass.

Sections from the large specimen with glassy surface showed that between the base of the specimen (about 7 in. from the surface) and about 1 in. from the surface the rock is fairly uniform in character, and consists of phenocrysts of olivine in a groundmass of smaller olivines and interlacing felspar laths with the interstices filled with glass so dense from separation of magnetite as to be opaque. As the surface is approached the amount of this dense glass increases. Then follows a zone in which the magnetite has separated in cloudy patches or cumulites, and also in thick seams round the olivine and felspar phenocrysts, leaving in the interspaces a clear yellow glass. To this succeeds a zone, in which there are no cumulites of magnetite, but the phenocrysts are still slightly coated, and the glass is darker and less transparent than in the preceding zone. Finally, on the surface is a clear light brown glass, in which occur olivines and felspars, but no magnetite whatever. The large porphyritic olivines in this glass are often corroded into fantastic shapes. Round one crystal the glass shows perlitic cracks. The smaller olivines are very sharply defined, and being so minute, show in the section actual faces of pinacoids and domes. Olivine also occurs in the form of forked skeleton crystals.

The felspar is mostly in sharply defined laths of labradorite, generally with ragged ends, but sometimes showing terminal c (001) and x ($\bar{1}01$) faces. It occurs also in extremely thin rhombic plates, showing zonal extinction and often enclosing olivine. These plates show traces of the faces c, x, and also of y ($\bar{2}01$). Supposing they are parallel to b (010) the extinction with respect to the trace of c varied from 4° in the centre to 16° on the edge. No augite microliths could be detected.

Some of the glassy basalts of the Rhöngebirge, *e.g.* the rocks from Schwarzenfels and Sterbfritz, present somewhat similar characters.

The specific gravity of the basalt about 7 in. from the glassy surface is 2·89: that of the glass on the surface 2·79.

The results of quantitative chemical analyses of this basalt and of the glass are as follows:—

Digitized by Google

Basalt (7in. from surface).				Basalt-Glass.
SiO_2	= 48·97	...	...	50·22
TiO_2	= 1·62	...	...	1·95
Al_2O_3	= 16·12	...	...	16·20
Fe_2O_3	= 1·90	...	...	8·18
FeO	= 9·63	...	...	8·07
MnO	= trace	...	...	trace
CaO	= 8·73	...	...	8·57
MgO	= 7·64	...	...	7·54
K_2O	= 1·21	...	...	1·88
Na_2O	= 2·99	...	...	3·36
Loss on ignition (mainly CO_2)	1·39	...	...	0·22
	100·20			100·64

In these analyses the same methods were used as in the case of the basalt from Franklin Island (p. 80). The weights taken of basalt and glass were respectively—1·4479 gram and 1·4090 gram for the determination of silica, etc.; 0·8525 gram and 0·6968 gram for the ferrous oxide; and 0·6150 gram and 0·6401 gram for the alkalies. The fairly close agreement between the analyses precludes the idea that anything in the way of differentiation has taken place within a depth of 7 inches. The slight differences in the percentages of silica, loss on ignition (carbonic acid), and ferric oxide, may be accounted for by the fact that in the basalt, as noticed in many specimens, there has been some slight development of chalybite at the expense of olivine, and that the glass has suffered a little surface oxidation.

Palagonite-Tuff.

A palagonite-tuff from an iceberg off Cockburn Island consists of fragments of precisely similar glass to that described above altering to orange-yellow palagonite, and cemented by chalybite, calcite, and zeolites. In character it corresponds almost exactly to a palagonite-tuff from Kerguelen Land, described by Renard.[1]

Granites.

Of the two specimens of granitic rocks from Cockburn Island, one with pink felspars, described on the label as a boulder, shows under the microscope very beautiful micropegmatitic structure of quartz and orthoclase. Oligoclase is also present, and altered biotite with green hornblende. The felspars are altered with development of epidote.

[1] *Challenger Reports*, VII. Petrography of Oceanic Islands, p. 116.

Digitized by Google

The other specimen, a chip of grey granite with sharp edges, is fresher, and shows no granophyric structure. It consists of quartz, orthoclase, oligoclase and microcline, with biotite in large ragged plates, and hornblende. The quartz is idiomorphic (in parts of the section giving hexagonal outlines) with respect to the microcline. The hornblende in prismatic sections is pleochroic from dull green to yellowish-brown, and shows polysynthetic twinning on $a(100)$.

Calcareous glauconitic Sandstone.

This rock consists of sub-angular grains of quartz and a little orthoclase and oligoclase (symmetrical extinction of twin laminæ about 5°), with grains of iron ore, zircon, pink garnet and green glauconite, all cemented by calcite. The quartz shows liquid inclusions with bubbles, and also hair-like inclusions such as occur in the quartz of many granitic rocks. The grains of iron-ore, zircon and garnet generally occur in strings; with them are a few deep-red pleochroic needles of a doubly-refracting mineral, possibly rutile.

A specimen obtained from an iceberg off Cockburn Island is a very fine-grained grey loosely coherent *sandstone*, showing to the naked eye here and there minute scales of glittering white mica. Under the microscope it is seen to consist of minute sub-angular grains of quartz and felspar and a little glauconite, with brown dusty interstitial matter.

A light greenish-grey compact *quartzite* from a piece of ice off Cockburn Island showed under the microscope a minutely crystalline aggregate of sub-angular quartz grains with indistinct flecks of a pale green hornblendic mineral giving the colour to the rock, a few rounded granules of zircon and a little felspar and mica.

Pebbles from a young penguin caught off Louis Philippe Land on December 31st, 1842, include specimens of *basalt*, *perlitic and spherulitic rhyolite*, *quartz-grit*, *slate* and *gneiss*.

The *basalts* present characters very similar to those of Cockburn Island, one specimen corresponding to the holocrystalline anamesitic type with ophitic augite, and the others to the more glassy varieties.

Of the *rhyolites* one specimen of a pale green colour showed to the naked eye phenocrysts of quartz and milk-white felspar. Under the microscope the quartz is seen to be rounded and penetrated by the magma: the felspar in large prismatic crystals is kaolinised and nearly opaque; some sections without twin laminæ show the parallel parting characteristic of sanidine, while others with fine twin laminæ are probably of oligoclase. The microfelsitic base consists of alternating

Digitized by Google

bands of light brown cloudy material showing flow-structure, and of clearer material exhibiting perlitic structure made evident by means of a pale green chloritic mineral.

Another milk-white rhyolite showing phenocrysts of quartz and felspar is seen under the microscope to consist of a dense cloudy microfelsitic base, showing in parts spherulitic structure with black crosses, in which are distributed large prismatic crystals of sanidine and smaller and more fragmentary and corroded crystals of oligoclase and quartz.

These rhyolitic rocks, like those collected during the second voyage, in both their macroscopic and microscopic characters are very similar to some of the Hungarian rhyolites.

The specimen of *quartz-grit* consists of angular grains of quartz (containing liquid inclusions) and felspar, with a little altered ferro-magnesian mineral.

Pebbles of dark-grey banded *slate* showed schistose structure with wavy dark bands encircling minute lenticular eyes of quartz-mosaic and calcite.

The specimen of *gneiss* shows quartz and orthoclase with foliation well marked by bands of pleochroic biotite. Oligoclase occurs in small amount, and a few rounded grains of zircon. Pœcilitic rounded quartz grains are present in the felspars.

In conclusion is appended the following list of the various kinds of rocks from Antarctic regions found in the Ross collection: –

From Auckland Islands (lat. 50°32′ S.; long. 166°12′ E.): *basalt.*

From Campbell Island (lat. 52°33′ S.; long. 169°8′ E.): *basalt, silicified globigerinal limestone, chert.*

From Possession Island (lat. 71°56′ S.; long. 171°7′ E.): *basalt, palagonite-tuff, phonolite, muscovite-granite.*

From Franklin Island (lat. 76°8′ S.; long. 168°12′ E.): *basalt (nepheline-basanite?).*

From Cockburn Island (lat. 64°12′ S.; long. 56°49′ W.): *basalt, palagonite-tuff, granite, calcareous glauconitic sandstone.*

From seals and penguins caught between lat. 63° S.; long. 151° W. and lat. 67° S.; long. 156° W.: *granite, epidiorite, dolerite, basalt, rhyolite, micaceous quartz-grit.*

From penguin caught off Louis Philippe Land in about lat. 64° S. long. 54° W.: *basalt, perlitic and spherulitic rhyolite, quartz-grit, slate, and gneiss.*

Digitized by Google

Riebeckite in Trachytic Rocks from Abyssinia.

By G. T. Prior, M.A., F.G.S.,
Assistant in the Mineral Department of the British Museum.

[Read Nov. 15th, 1898.]

IT is now ten years since Sauer[1] first described under the name of riebeckite a new species of blue hornblende in the granite of Socotra.

Since that time its occurrence in the British Isles has been noted in the "felsite" of Mynydd Mawr,[2] N. Wales; in the "microgranite" of Ailsa Craig,[3] Firth of Clyde; in glacial deposits from the Isle of Man; Moel Tryfaen,[4] N. Wales; Greystones, Co. Wicklow[5]; and Greenore, Carlingford[6]; in granophyre from Meall Dearg,[7] Skye; and in felsite from Middle Eildon,[8] Roxburghshire.

On the Continent it has been recorded in "granulite" from Corsica,[9] in the trachyte of Berkum,[10] Rhine, and in a minette from Wackenbach, Vosges.[11]

In America riebeckite and blue hornblendes allied to it have been described from Colorado[12] (El Paso Co. and Silver Cliff), Texas[13] (Paisano Pass), Michigan (Lake Superior region),[14] and California (Berkeley).[15]

In India it has been noted in a granite from Southern Sikkim.[16]

---

[1] "Ueber Riebeckite, ein neues Glied der Hornblendegruppe." *Zeits. deutsch. geol. Ges.* XL. (1888), p. 138.

[2] Bonney, *Min. Mag.* VIII. (1888), pp. 103, 169; Harker, *Geol. Mag.* 1888, p. 455.

[3] Teall, *Min. Mag.* IX. (1891), p. 219; Heddle, *Trans. Edin. Geol. Soc.* VII. (1897), p. 265.

[4] Cole, *Min. Mag.* IX. (1891), p. 222.

[5] Sollas, *Proc. Roy. Irish Acad.* III. (1895), p. 516.

[6] Cole, *Nature*, XLVII. p. 464.

[7] Teall, *Quart. Journ. Geol. Soc.* 1894, p. 219.

[8] Barron, *Geol. Mag.* 1896, p. 371.

[9] Le Verrier, *Compt. Rend.* CIX. (1889), p. 38.

[10] Rosenbusch, *Mikr. Phys.* II. p. 770, 1896.

[11] Rosenbusch, *ibid.* p. 510, 1895.

[12] Lacroix, *Compt. Rend.* CIX. (1889), p. 39; König, *Zeits. Kryst.* 1, p. 430; Cross, *Am. Journ. Sci.* XXXIX. (1890), 359.

[13] Osann, *Geol. Survey of Texas*, 4. *Annual Report*, 1893.

[14] Lane, *Am. Journ. Sci.* XLII. (1891), 508.

[15] C. Palache, *Bull. Dept. Geol. Univ. California* 1 (1894), 185.

[16] Holland, *Records Geol. Survey India*, XXV. pt. 3, 1892.

Digitized by Google

The object of this note is to place on record a new occurrence of riebeckite in trachytic rocks from Abyssinia.

The specimens in the British Museum in which the riebeckite was found form part of a collection of rocks made by Mr. W. T. Blanford when acting as geologist to the Abyssinian Expedition of 1868 under Sir Robert Napier.

In his book, *Observations on the Geology and Zoology of Abyssinia* (London: Macmillan & Co. 1870), Blanford describes the geological features of the country traversed by the Expedition from Annesley Bay on the Red Sea to Magdala.

The following details as to the mode of occurrence of the trachytic rocks are drawn from that work.

The fundamental rocks of the province of Tigre "and probably of all Abyssinia" are metamorphics. On the route to Magdala almost all hills exceeding 8,000 ft. in height above the sea were found to consist of bedded traps (trachytes and basalts). Between the metamorphics and the traps occur a series of sandstones and limestones, the latter alone fossiliferous and of Jurassic age.

The volcanic rocks were first met with at Senafé, which lies in a plain with hills on both sides generally composed of basalt and trachyte, the latter predominating. The highest point, Akúb Teriki (or Arabi Teliki), 9,000 feet high, a most conspicuous object to the north of Senafé, consists near its base of basalt and trachyte, with a flat top composed of a coarse "trachyte" resembling sandstone. It was not clear whether this mass is intrusive or whether it fills a hollow in the metamorphics. About 8 miles W. by S. of Senafé is the trachytic hill of Kishyat, the north face of which is precipitous and consists of "magnificent vertical columns extending the whole height of the cliff, upwards of 300 feet, without a single break."

Similar hills of "trachyte" are dotted over the country to the south as far as Fokada, a distance of nearly 30 miles. These were regarded by Blanford as probably the remains of the same great lava flow. The columnar trachyte of a hill near Fokada closely resembles that of Kishyat; here it rests on basalt, which again overlies unconformably the Adigrat sandstone. These trachytic hills are described as rounded hummocks of very peculiar shape, suggestive rather of granitic than of trachytic masses. The geological age of the trachyte is uncertain, as no other formation rests upon it.

The specimens containing riebeckite which form the subject of this note come from Akúb Teriki, Kishyat, and Fokada.

Digitized by Google

The trachyte from the hill near Fokada is a fine-grained pale lavender-coloured rock, showing to the naked eye a few porphyritic crystals of glassy felspar. Under the microscope it exhibits trachytic structure, and is seen to consist of a felt of small lath-shaped felspars with a little quartz, uniformly distributed in which occurs in moss-like sub-ophitic patches the riebeckite, presenting much the same appearance as it does in the Mynydd Mawr rock. In this groundmass porphyritic crystals of felspar (probably anorthoclase), mostly in Carlsbad twins, occur sparingly, either singly or in groups. In this respect, as well as in the character of the groundmass, the rock bears a more striking resemblance to the well-known trachyte of the Hohenberg at Berkum, near Remagen, on the Rhine, than to the Mynydd Mawr rock.

This Berkum trachyte is referred by Rosenbusch to a special arfvedsonite (riebeckite) type of trachyte. Examination of a specimen in the Museum collection shows that the blue hornblende in moss-like patches which it contains presents precisely the same pleochroism (deep indigo-blue to pale yellowish-brown) as that in the Mynydd Mawr rock, and that the *a* (not the *c*) axis of the indicatrix is the one nearly coincident with the vertical crystallographic axis *c*.

In the Abyssinian rock the blue hornblende shows similar characters. Prismatic sections compensate with the quartz wedge along their length, and give low angles of extinction (in one section about 5°). Such sections show pleochroism from a dirty pale yellowish-brown to deep indigo-blue (almost black). In a section showing the prismatic cleavage (inclined at an angle of about 120°) the pleochroism was from deep blue to pale yellowish-brown. For the three axes of the indicatrix we have therefore—

a (nearly parallel to *c*)=dark indigo-blue,
b (bisecting the acute angle of the cleavage)=deep blue,
c=pale yellowish-brown.

This is precisely similar to the pleochroism in the rocks from Mynydd Mawr, Berkum, and Ailsa Craig, but differs slightly from that of the original riebeckite from Socotra, in which, according to Rosenbusch, *c*=green.

The section of the trachyte from Kishyat presents somewhat similar characters to that of the rock from Fokada, but is slightly coarser-grained and contains more quartz; in the specimen examined the moss-like riebeckite was to a large extent converted into a black alteration product.

A minute crystal fragment of riebeckite detached from a cavity in this rock has at my request been measured by my colleague, Mr. L. J.

Digitized by Google

Spencer. The fragment showed the following forms :—m(100), four planes; n(310), a single narrow plane, new for riebeckite; c(001), z(021), a(100), one plane of each; a m n were striated vertically, and c and z parallel to their intersections. The following measurements were made :—

	Measured (L.J.S.)	Calcd. for Riebeckite (Sollas).	Hornblende (Dana).
110 : 1$\bar{1}$0	54° and 56¼°	m m 56°	m m 55°49′
001 : 100	76°15′	a c 76°10′	a c 73°58½′
001 : 110	77°46′	c m 77°50′	c m 75°52¼′
021 : 001	29°46′	c z 29°36′	c z (29°27′), not an
021 : 110	65°5′	z m 65°28½′	[observed form
021 : 100	77°39′	a r 78°0′	
100 : 310	9°0′	a n (10°3′), not an observed form	a n 10°0¼′

The rock from Akúb Teriki is of a somewhat different type to those from Fokada and Kishyat. Instead of being rough and porous as they are, it is compact, with a peculiar scaly appearance, rather like some phonolites. The microscopic characters suggest that it may be an intrusive rock. The groundmass consists of a felt of lath-shaped felspars similar to that of the preceding rocks, but of much coarser grain. Large phenocrysts of glassy felspar (probably anorthoclase[1]) occur, in some of which are included rectangular sections of zircon, showing in convergent light a positive uniaxial figure. In this rock the riebeckite is accompanied by grass-green ægyrine, and in less amount by a brown hornblende, with which it often forms intergrowths similar to those described by Whitman Cross (*loc. cit.*) in the rock from Rosita Hills, Silver Cliff, Colorado. Irregular sections of hornblende (showing pleochroism from light brown to deep brownish-black) intergrown with ægyrine (compensating along the length of prismatic sections and showing pleochroism from grass-green to yellow), are fringed with tuffs of indigo-blue riebeckite.

This last rock, as well as the preceding, if intrusive, would fall into the "Paisanite" group of Rosenbusch, in which he includes the rocks from Mynydd Mawr and Ailsa Craig as well as the riebeckite rock described by Osann (*loc. cit.*) from Paisano Pass, Texas, which gives its name to the group.

[1] Extinction on c(001) 0°—2°, on b 010) 9°—12°; strong sodium flame.

Digitized by Google

Minerals from Swaziland: Niobates and titanates of the rare earths, chemically allied to Euxenite and Fergusonite; Cassiterite, Monazite, &c. The "Æschynite" from Hitterö.

By G. T. Prior, M.A., F.G.S.,

Assistant in the Mineral Department of the British Museum.

[Read April 5th, 1898.]

THE specimens described in this note were collected by Mr. Sydney Ryan, Managing Director of the Ryan Tin Mines, and were presented by him to the British Museum through Mr. John Ballot, who brought them to England.

They were found in the stanniferous gravels of the Embabaan district in Swaziland, S. Africa. Their probable source is the granite-gneiss which forms the base of the rock-series in that district.[1]

The species represented in Mr. Ryan's collection include euxenite- and fergusonite-like minerals, cassiterite, monazite, scheelite, corundum, magnetite and garnet.

Mineral chemically allied to Euxenite.

This mineral was found in loose tabular crystals, which are very rough and worn, and not suitable for accurate measurement. One crystal, in size about $3 \times 3 \times 1$ cm, shows the faces of two prisms, pinacoid (tabular faces) and basal plane. In habit it is very similar to the large crystals from Hitterö, described and figured by Brögger under the name of Æschynite in *Zeitschr. Kryst.* III. (1879), 481, figs. 18 and 19. Measurements with the contact-goniometer gave angles of about 118° and 54° respectively for the two prisms, and an angle of about 90° between base and pinacoid.

In physical characters it is also like the Hitterö mineral. The fracture is sub-conchoidal, with a brilliant vitreous to greasy lustre. The colour is brownish-black; that of the fine powder pale buff. In thin splinters the mineral is translucent, with a yellowish-brown colour, and is isotropic.

[1] The geology of the district is described by Prof. T. Rupert Jones in the *Geol. Mag.* for March, 1899.

Digitized by Google

The specific gravity is 4·996, as determined by hydrostatic weighing on a crystal weighing 28 grams.

Two quantitative analyses (I. and II.) were made on 1·2291 gram and 1·2788 gram respectively. The combined result is given under III.

	I.	II.	III.	Molecular Ratios.
Nb_2O_5	36·68	58·17	36·68	·1369
TiO_2	21·69		21·89	·2664
SiO_2	2·12		2·12	·0371
ThO_2		0·61	0·61	·0024
SnO_2	0·29		0·29	·0020
Y_2O_3, Er_2O_3	18·13	17·11	17·11 (molr. weight, 246)	·0696
Ce_2O_3, La_2O_3, Di_2O_3	3·22	4·32	4·32 (molr. weight, 310)	·0140
UO_3	3·16	2·14	2·14	·0074
UO_2		0·49	0·49	·0018
FeO	5·65	5·60	5·63	·0782
CaO	4·19	4·06	4·12	·0736
MnO		0·19	0·19	·0027
MgO	0·22		0·22	·0055
H_2O	3·69		3·69	·2050
			99·50	

Method of Analysis.

In the first analysis the mineral was decomposed by fusion with acid potassium sulphate. The insoluble residue of niobic acid with part of the titanic acid, left on extracting with cold water, was again fused with the sulphate. The insoluble residue left on again extracting with cold water was treated with ammonium sulphide, and then with dilute hydrochloric acid, and afterwards washed, ignited and weighed. In the water extracts the rest of the titanic acid was precipitated by long-continued boiling. The rare earths, together with iron and uranium, were then separated from calcium, &c., by a double precipitation with ammonia. The cerium and yttrium earths were separated from iron and uranium by means of oxalic acid, the iron from uranium by means of ammonium carbonate and sulphide, and the cerium from the yttrium earths by a double precipitation with potassium sulphate. The yttrium earths obtained from the filtrate after the second precipitation with potassium sulphate were slightly coloured by cerium earths, so that the number given in this analysis for the yttria is probably too high. The

Digitized by Google

titanic acid retained in the niobic acid precipitate was determined in the following way. The precipitate was brought into solution in hydrofluoric acid, and potassium fluoride added in order to test for tantalic acid. The solution was then evaporated down with a large excess of sulphuric acid, and the residue gently ignited in order to expel all the hydrofluoric acid. It was then treated with cold water in large excess, and the solution filtered from the slight insoluble residue. The titanic acid in the filtrate was then colorimetrically determined by means of hydrogen peroxide. It amounted to nearly one-half of the total percentage in the mineral.

The silica was determined in a separate portion of the powdered mineral by fusion with soda, extracting with dilute soda solution, acidifying and evaporating to dryness. The silica was estimated as the loss of weight on heating with hydrofluoric and sulphuric acids the insoluble residue thus obtained.

In the second analysis the mineral was decomposed by fuming hydrofluoric acid according to the method of Lawrence Smith (*Original Researches in Mineralogy and Chemistry*, p. 352). Most of the uranium was found in the hydrofluoric acid solution of the metallic acids.

In this analysis the cerium and yttrium earths were separated by only a *single* precipitation with potassium sulphate. The molecular weights were determined in the usual way by converting the oxides into sulphates; that for the cerium earths is only approximate since it is calculated by considering the ignited oxides as sesquioxides. An imperfect separation of the cerium from the lanthanum and didymium oxides, by precipitating with potash and saturating with chlorine, suggested that the latter oxides were present in about double the amount of the former. In stating the result of the analysis, I have preferred to give the approximate molecular weights of the yttrium and cerium earths respectively, rather than ascribe to the individual earths percentage numbers which, with our present means of separation, can have but little value.

The thoria was separated from the cerium earths by precipitation with sodium thiosulphate. After ignition and weighing, the oxide, which was perfectly colourless, was tested by dissolving in dilute sulphuric acid, evaporating the solution to dryness and gently igniting the residue to expel the excess of acid. The residue dissolved in cold water, giving a clear solution in which oxalic acid produced a precipitate insoluble in excess. On adding ammonia until neutral or even slightly alkaline, this precipitate dissolved, yielding a perfectly clear solution, in which the thoria was re-precipitated on addition of excess

Digitized by Google

of concentrated hydrochloric acid. These details are given since some discrepancies appear to have crept into the literature as to the behaviour of thorium with respect to ammonium oxalate.

The numbers obtained in the analyses suggest the formula—

$$2R_2O_3.4RO.6TiO_2.4Nb_2O_5.5H_2O,$$

$$\text{or } R'''_2(TiO_3)_3.2R'''(NbO_3)_3+3R'(TiO_3).R'(NbO_3)_2+5H_2O.$$

In chemical composition the mineral is more closely related to euxenite than to æschynite.

In the habit of the crystals, however, as mentioned above, it is very similar to the "æschynite" from Hitterö described and figured by Brögger.

It seemed advisable therefore to make at least a qualitative examination of material from crystals of the Hitterö mineral in the Museum collection.

The "Æschynite" from Hitterö.

In habit the crystals of this mineral in the British Museum correspond precisely to Brögger's description. They are tabular parallel to $b\{010\}$, and show the two prisms $n\{130\}$ and $m\{110\}$, the basal plane $c\{001\}$, with the dome $x\{021\}$, and very rarely a pyramid. Measurements made with the contact goniometer varied somewhat in different specimens, owing to the roughness of the faces, but the smaller and more perfect crystals gave values agreeing somewhat closely with those of Brögger. Thus four fairly good crystals gave $nn' = 110°$ (109°32′ of Brögger): one of these showed also the prism m and gave $mm' = 52°$ (51°26′ of Brögger); while another showed the dome x and gave $xx' = 106°$(106°44′ of Brögger). Other larger crystals, however, with more rounded faces, gave for the prism nn' angles varying from 102° to 117°, while for xx' two crystals gave an angle as low as 101°. In spite of this there was little reason to doubt that the material in the Museum collection was specifically identical with that described by Brögger.

A qualitative analysis of material from one of the crystals showed that it was similar in composition to the Swaziland mineral, and that chemically it was therefore more closely related to euxenite than to æschynite. Besides niobic and titanic acids, it contained yttrium and cerium earths (the latter in much smaller amount than the former), with iron, uranium and calcium, and little or no zirconium or thorium. The titanic acid appeared to be in larger amount than in the Swaziland mineral. This result showed that in all probability the material from Hitterö *analysed*

Digitized by Google

by Jehn[1] and termed by him *euxenite*, was identical with the crystallised material *measured* by Brögger and referred by him to *æschynite*.

Prof. Brögger in his paper (*loc. cit.*) carefully states that the mineral which from his crystallographic examination he thus refers to æschynite, may possibly be no true æschynite, but another mineral isomorphous with it, and that this can only be decided by an exact chemical analysis.

The results which I had obtained were therefore communicated to Prof. Brögger, and in reply he has very kindly furnished me with the information that since the publication of his paper, at his request the late Prof. Blomstrand analysed specimens of the "æschynite" from both Hitterö and Arendal, and that these analyses, which have not yet been published, confirm the above result, that these minerals are chemically closely related to euxenite, and not to æschynite.

Prof. Brögger considers that, as shown in his paper, crystallographically this Hitterö mineral has nothing to do with euxenite, but belongs undoubtedly to the æschynite type, and that therefore the Hitterö mineral should receive a new name.

In the present note I have preferred to describe the mineral from Swaziland as a euxenite-like mineral and not under a new name, since, owing to the imperfect state of the crystals, its specific identity with the mineral from Hitterö is not absolutely beyond doubt.

Fergusonite?

The mineral, in the absence of crystals doubtfully referred to fergusonite, was in small rounded lenticular pebbles, and also in rounded fragments intimately intergrown with monazite.

The specific gravity of material of both modes of occurrence was practically the same (5·43 and 5·42). Qualitative analysis in each case showed the presence of water, much niobic acid, iron, uranium and yttrium earths, with very little titanic acid or cerium earths.

Cassiterite.

The specimen of cassiterite was not from the stanniferous gravels, but showed the mode of occurrence of the mineral in crystals in the matrix, a coarse-grained quartz felspathic rock, probably a vein in the granite-gneiss.

The crystals consisted of long apparently rhombic prisms (up to 2 cm. long and 3-4 mm. broad), suggesting an orthorhombic rather than a

[1] Jehn, *Inaug. Diss.* Jena, 1871. Analysis quoted by Dana, *Syst. Min.* 1892, 744.

Digitized by Google

tetragonal mineral, and it was only after chemical examination that they were referred to cassiterite.

Measurement of some crystal fragments, made by Mr. L. J. Spencer, showed that the apparently prismatic habit was due to the elongation of the crystals in the direction of the pyramidal edges [$11\bar{1}$, $\bar{1}11$]. The angle between these faces = 58°—59° (for cassiterite $ss' = 58°19'$). On two crystals, besides these s planes, terminal faces $a\{100\}$, $m\{110\}$, $e\{101\}$ were identified.

A similar apparently orthorhombic habit in tetragonal minerals has been noted, in the case of rutile by Pirsson[1], and by Miklucho-Maclay[2]; and in the case of tapiolite by Brögger[3] and by Warren.[4] Brögger (loc. cit.) shows that corresponding to columbite and tantalite are the dimorphous tetragonal forms mossite and tapiolite, and that the skogbölite of Finland is identical with tapiolite, the apparently orthorhombic habit being due to twinning about a pyramid, and to the extension of some of the pyramidal faces into a prismatic form, as in the case of this cassiterite from Swaziland.[5]

Monazite.

The specimens of monazite consist of rough tabular crystals from the gravels; the predominent pair of faces being $a\{100\}$.

By means of the contact goniometer the following forms were identified: $a\{100\}$, $m\{110\}$, $w\{101\}$, $c\{001\}$, $v\{\bar{1}11\}$, $\frac{1}{4}\{305\}$.

The specific gravity of one of the larger crystals was 4·62. Qualitative analysis showed the presence of phosphoric acid, and cerium earths with some silica and thoria. The latter was separated from the cerium earths by means of sodium thio-sulphate, and the precipitate was tested in the way described above on p. 98.

---

[1] *Am. J. Sci.* XLI. 1891, 249.

[2] *Neues Jahrb. f. Min.* 1885, ii. 89.

[3] *Videnskabsselskabets Skrifter*, 1 *Math.-Natur. Klasse*, 1897, No. 7, Kristiania.

[4] *Am. J. Sci.* 1898, VI. 116.

[5] Since the above description was written, I have received from Prof. Molengraaff a copy of the recently published Annual Report of The State Geologist of the South African Republic for the year 1897, in which he describes and figures, in his account of the occurrence of Tinstone in Swaziland, crystals precisely similar to those described above.

Digitized by Google

On some lead minerals from Laurium, namely, Laurionite, Phosgenite, Fiedlerite, and (new species) Paralaurionite.

By G. F. Herbert Smith, B.A.,

With Chemical Analysis by G. T. Prior, M.A., F.G.S.,

Assistants in the Mineral Department of the British Museum.

[Read April 5th, 1898.]

In this paper are embodied the results of an examination of the specimens of lead slags from Laurium in the British Museum. On some of the specimens a new mineral, paralaurionite, was found, which possesses the same chemical composition as laurionite, but entirely different morphological and optical characters.

In addition to crystals of the four minerals given in the title, a few crystals of matlockite and anglesite were noticed, and on one specimen there is a radiating group of prismatic crystals of penfieldite.

I. Laurionite.

(*a*) *The morphological characters.*

Laurionite crystallises in the orthorhombic system. The axial ratios were calculated from the angles between the faces $bn^1(010:120)$ and $bd(010:012)$, and found to be—

$$a:b:c = 0{\cdot}7885:1:0{\cdot}8346$$

The following values have been previously obtained by Dr. R. Köchlin and Prof. vom Rath—

$$a:b:c = 0{\cdot}7328:1:0{\cdot}8315 \quad \text{Köchlin}^2$$
$$0{\cdot}7178:1:0{\cdot}8125 \quad \text{vom Rath}^3$$

---

[1] Throughout this paper the same letters are used for the faces as in Dana's *System of Mineralogy*, Sixth Edition.

[2] *Annalen naturhist. Mus. Wien*, 1887, II. 188, and II. 83 and 127 (Notizen). Dr. Köchlin was the first to describe Laurionite.

[3] *Ber. niederrhein. Ges.* p. 150, June 6th, 1887. Prof. vom Rath took the pyramid face *p* as parametral plane. The values given above have been calculated from his measurements.

Digitized by Google

Three distinct habits were observed, of which two have already been described by Dr. Köchlin,[1] but in the case of the third the crystals are terminated entirely by new forms.

The first consists simply of the forms $b(010)$, $m(110)$, and $n(120)$, lying in the prism zone, and the dome $d(012)$.

The second is distinguished by the pyramid form p, whose indices appear to be either (151) or (141). The faces often yield more than one distinct image, sometimes three or four. In determining the position of these faces the vertical-circle devised by Dr. Stöber[2] was employed, and readings were taken of each image separately, $b(010)$ being the pole. The polar distance (*i.e.* the angle bp) varies from 19°0′ to 27°12′, and the azimuthal angle (measuring from the prism zone) from 37°52′ to 47°47′. The values of these angles for (141) and (151), calculated from the axial ratios, are—

		Polar distance.	Azimuth.
(151)	...	19°0′	41°40′
(141)	...	24°19½′	41°40′

When this form is present, the faces of the form b are always striated parallel to their intersections with p, and give multiple images, and the crystals, owing to the oscillation of b with p, often taper towards the top. It would appear that the faces of the form p are vicinal, and possibly due to etching.

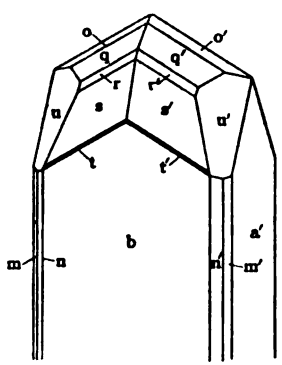


Fig. 1.

The third habit (Fig. 1) is remarkable for a number of new pyramid

[1] *Loc. cit.*, where figures of the two types may be seen.

[2] *Zeits. Kryst. Min.* 1897, XXIX. 25. Abstract in this vol. p. 52.

Digitized by Google

forms:—$o\{112\}$, $q(122)$, $r(132)$, $s(142)$, and $t(152)$, lying in a zone with $b(010)$, and $u(232)$.

In all the following forms have been observed on these crystals:—

$b(010)$ The largest face. Gives good image except in the case of crystals with the pyramid form p.
$a(100)$ Small, gives distinct image.
$m(110)$ Good image.
$n(120)$ Smaller than m, but usually gives better image.
$d(012)$ Small, but gives good image.
$p(151)$ or (141) See above.
$o(112)$ Small; image poor, but only once measured.
$q(122)$ Large; good image.
$r(132)$ Small; image poor.
$s(142)$ Large; good image.
$t(152)$ Minute; image only once seen.
$u(232)$ Large; good image.

In the following table will be found the calculated and observed values of the measured angles:—

Angle.	Calculated.	Observed Mean.	Limits.	Edges.
010 : 120 *bn*		34°6′	33°59′ —34°17′	26
010 : 110 *bm*	58°33′	58 45	58 17 —54 14	26
010 : 012 *bd*		67 21	67 16 —67 28	7
010 : 112 *bo*	70 2	69 34		1
010 : 122 *bq*	54 0	54 1	53 21 —54 24	6
100 : 122 *aq*	66 33	66 29	66 25½ —66 34½	4
010 : 132 *br*	42 32½	42 24	41 29 —42 59	6
010 : 142 *bs*	34 32	34 34	34°18′, 34°41′, 34°43′	3
010 : 152 *bt*	28 50	29 4		1
100 : 232 *au*	54 48	54 40		1
010 : 232 *bu*	50 19½	50 32	50°26′ —50°39′	4

The crystals are about 3·4 mm. in length.

(*b*) *The optical characters.*

Little information is to be obtained by placing a crystal between the crossed nicols of a polariscope. On looking through b, usually the only large face, no interference figure can be seen, and it would appear that the plane of the optic axes is parallel to this form. Among all the crystals observed only one possessed faces of the form a large enough for optical purposes. In this case an ordinary biaxial figure was

Digitized by Google

seen, but even when cedar oil was employed the "eyes" did not come into the field of view. If we assume that the acute bisectrix is perpendicular to a, the crystals are optically negative.

The prisms available for the determination of the principal indices of refraction are those given by the forms bm and mn. Since these are not symmetrical with regard to a plane of symmetry, the labour of calculation is considerably increased. It was not found possible to avoid this difficulty; the interior angles of prisms belonging to the same form are, with one exception, too large (the exception is dd', 45°18′, but unfortunately the crystals are never doubly terminated), and it is impossible to produce artificial faces on such small crystals.

Observations were made of the deviations of the two rays corresponding to different angles of incidence in sodium light, and the indices were deduced from the formulæ due to Sir George Stokes.[1]

A central section of the wave-surface by a plane parallel to (001) gives two curves, a circle and an ellipse—

$$\left.\begin{aligned} x^2+y^2&=c^2 \\ a^2x^2+b^2y^2&=a^2b^2 \end{aligned}\right\}$$

Where $a=1/\alpha$, $b=1/\beta$, and $c=1/\gamma$; $\alpha\,\beta\,\gamma$ being the principal indices of refraction. The image, which corresponds to the circle, and whose plane of polarisation is at right angles to the prism edge, behaves exactly as if the crystal were isotropic. We have therefore in this case the formulæ—

$$\tan\left(r_1-\frac{A}{2}\right)=\tan\frac{A}{2}\cdot\tan\left(i-\frac{A+D_1}{2}\right)\cot\frac{A+D_1}{2}$$

$$\gamma=\sin i\,/\sin r_1$$

Where A is the prism angle, i the angle of incidence, D_1 the angle of deviation, and r_1 the angle of refraction at the incident face.

The second image, which corresponds to the ellipse, and whose plane of polarisation is parallel to the prism edge, gives formulæ involving the remaining two indices of refraction—

$$\tan\left(r_2-\frac{A}{2}\right)=\tan\frac{A}{2}\cdot\tan\left(i-\frac{A+D_2}{2}\right)\cot\frac{A+D_2}{2}$$

$$p=\sin r_2\,/\sin i,\ \psi=\frac{\pi}{2}+\left(r_2-\frac{A}{2}\right)$$

$$p^2=a^2\cos^2(\psi-\mu)+b^2\sin^2(\psi-\mu).$$

Where D_2 is the angle of deviation, r_2 the angle of refraction at the inci-

[1] G. G. Stokes, "On a formula for determining the optical constants of doubly refracting crystals," *Camb. and Dub. Math Journal*, 1846, I. 183. *Cf.* Liebisch, *Physikalische Krystallographie*, Leipzig, 1891, p. 394.

Digitized by Google

dent face, and μ the angle between the plane bisecting the prism angle and the face (100).

We obtain several equations for a and b, and solve them by the method of least squares.

It should be remarked that in the determination of a and b we have to find the semi-axes of an ellipse, being given the lengths of perpendiculars from the centre on tangents, and the angles these perpendiculars make with one or other of the axes. If the values obtained are to be accurate, observations should be taken over as much of a quadrant as possible. Observations taken near the extremity of an axis will give an accurate value of this axis, but not of the other, whilst those in the middle of the quadrant will give values of both axes of about equal accuracy.

The images given after refraction through the prisms *bn* and *mn* were so good that in the former case 16 different angles of incidence were used, varying from about 28° to 78°, and in the latter 10 different angles, varying from 22° to 68°. The resulting values of $(\psi-\mu)$, *i.e.* the angle the perpendicular makes with an axis—in this case the normal to (010)—vary from 6° to 28° in the first, and from 45° to 60° in the second case. Since then one set of observations is taken near the extremity of an axis and the other near the middle of the quadrant, we may reasonably expect the resulting values to be fairly accurate.

Since the faces of the prism do not belong to the same form, it is necessary to notice on which face the light is incident, for except when a minimum the deviation of the extraordinary ray for the same angle of incidence will not be the same in the two cases.

The following are the values of the principal indices of refraction for sodium light—

$$\alpha = 2{\cdot}0767$$
$$\beta = 2{\cdot}1161$$
$$\gamma = 2.1580 \text{ (varying from } 2{\cdot}1499 \text{ to } 2{\cdot}1658).$$

Whence we see that the plane of the optic axes is parallel to (010).

The acute bisectrix is perpendicular to (100), and the angle between the optic axes in the crystal is found on calculation to be 81°32′. The rays parallel to these axes do not emerge through the face (100) into air, and even when the medium is a highly-refracting liquid the angle is too large for the "eyes" to be visible in the polarising microscope.

Digitized by Google

II. Phosgenite.

The crystals of this mineral are remarkably colourless and transparent, and have very smooth faces. The observed forms are: $c(001)$, $a(100)$, $m(110)$, $h(210)$, $o(201)$, $x(111)$, and $s(211)$. The values of the measured angles are almost identical with those obtained by Koksharov on crystals from Monte Poni.[1]

The prisms formed by the faces $hh^5(210:\bar{1}\bar{2}0)$ and $ah^3(100:\bar{2}10)$ were used in the determination of the refractive indices. The means of ten values for sodium light are—

$\omega = 2{\cdot}1181$ Limits $2{\cdot}1158$—$2{\cdot}1205$

$\epsilon = 2{\cdot}1446$ $2{\cdot}1423$—$2{\cdot}1467$

III. Fiedlerite.

(*a*) *The morphological characters.*

Thin tablets of this mineral mingled with crystals of laurionite were occasionally observed. The habit is identical with that described by Prof. vom Rath.[2] On only a few of these tablets were the faces found to give on reflection distinct images. The observed forms are: $a(100)$, $c(001)$, $m(110)$, $n(650)$, $d(101)$, $x(\bar{1}01)$, $y(\bar{2}01)$, $e(154)$ and $o(554)$; of which $d(101)$ is new. Prof. vom Rath chose o as the parametral plane, and found for x the indices $(\bar{5}06)$; those of m are the same as above, namely (110). There are two reasons for the change of parameters here made: the form o has been rarely observed, and, if it be used to determine the axial ratios, the resulting indices for the prism forms are not simple.

System: monoclinic. Axes $a : b : c = 0{\cdot}8299 : 1 : 0{\cdot}7253$; $\beta = 77°31'$. The following table gives the calculated and observed values of the measured angles:—

---

[1] *Mat. Min. Russl.* 1881, VIII. 118.

[2] *Ber. niederrhein. Ges.* p. 154, June 7th, 1887.

Digitized by Google

Angle.	Calculated.	Observed Mean.	Limits.	Edges.
100 : 001 *ac*		77°31′	77°16′—77°39′	10
100 : 101 *nd*		41 51	41 31 —42 10	5
100 : 110 *am*		39 1	38 34 —39 24	7
$\bar{1}00$: $\bar{2}01$ *a′y*	32°30½′	32 33	32 18 —32 50	7
$\bar{1}00$: $\bar{1}01$ *a′x*	56 1	56 13	55 51 —56 29	7
100 : 650 *an*	34 2	33 46	33°33′, 33°37′, 34°8′	3
100 : 154 *ae*	71 45	71 41	71 12 , 71 54 , 71 56	3
100 : 554 *ao*	45 12	44 46		1
[010]:[$0\bar{4}5$] *cao*	42 12	41 48	41°34′—41°57′	4

The tablets are never more than 5 mm. square. A few crystals were twinned about *a*.

(*b*) *The optical characters.*

On placing a tablet between the crossed nicols of a polarising microscope and using monochromatic light, an interference figure may be seen. The axis of crystalline symmetry is the obtuse bisectrix, and the acute bisectrix is inclined at a small angle to the normal to *a*. The sign of the birefrigence is negative.

The prism *ay* was employed to determine the principal indices of refraction, and the same method used as in the case of laurionite, but the angle μ is no longer constant for different colours, and cannot be determined from the geometry of the crystal. It is difficult to find μ accurately, and hence the values obtained for α and γ can only be regarded as approximate.

The values obtained for sodium light are—

$\beta = 2{\cdot}1023$, mean of 16 values ranging from 2·0988—2·1090
$\gamma = 2{\cdot}026$ approx.
$\alpha = 1{\cdot}816$,,

The angle between the normal to (100) and the acute bisectrix is about 6°.

IV. Paralaurionite, a new mineral.

(*a*) *The morphological characters.*

Crystals of this mineral may at a cursory glance be easily mistaken for laurionite or fiedlerite, according as their form is prismatic or tabular. The crystalline symmetry is monoclinic, but almost always pseudorhombic owing to twinning.

Digitized by Google

The axial ratios have been calculated from the angles *am* and *ap*, and the angle β (100 : 001) has been measured direct. These constants are—

$$a : b : c = 0{\cdot}8811 : 1 : 0{\cdot}6752\,;\ \beta\ (100 : 001) = 62°47'.$$

Two types of crystals have been observed: tabular (Fig. 2), the faces of the form *c* at the back being usually given by cleavage on extracting the crystal; and prismatic, elongated parallel to the edge *ac*, and terminated at one end only without the form *p*.

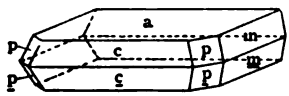


FIG. 2.

The following forms have been observed—

a(100) Large; image good.
c(001) Small; image distinct. This is the cleavage face.
d(10$\bar{1}$) Minute; image bad.
h(20$\bar{1}$) Small; image distinct.
k(40$\bar{1}$) Small; image poor.
l(60$\bar{1}$) Small; image poor.
p(111) Large; image good.
m(110) Large; image good.

The following table gives the calculated and observed values of the measured angles—

Angle.		Calculated.	Observed Mean.	Limits.	Edges.
100 : 001	*ac*		62°47′	62°16′—63°53′	31
100 : 10$\bar{1}$	*ad*	76°48½′	77 0	75 52 —77 42	4
100 : 20$\bar{1}$	*ah*	45 24½	45 24	45 19 —45 50	9
100 : 40$\bar{1}$	*ak*	21 55	21 34	20 57 —22 45	9
100 : 60$\bar{1}$	*al*	14 5	13 53	13°49′, 13°50′, 14°0′	3
100 : 110	*am*		67 25	67°22′—67°36′	16
100 : 111	*ap*		58 28	57 55 —58 46	16
001 : 111	*cp*	52 37½	52 39	52 33 —52 43	4
001 : 110	*cm*	79 53	79 55	79 30 —80 12	6
[010]:[01$\bar{1}$]	*cap*[1]	60 59	61 7½	61°3′, 61°12′	2

The prismatic crystals are often as much as 5 mm. in length, and the tablets as much as 15 × 10 mm. in area.

[1] Three crystals only were measured with the vertical circle.

Digitized by Google

(b) The optical characters.

The interference figure seen through *a* in *monochromatic* light (very little can be seen in white light) is similar to that visible through the face (100) of a diopside crystal, twinned about that face,[1] and as in this case the relative size of the two sets of rings depends on the relative thickness of the two individuals. The interference figure affords the simplest method of distinguishing between crystals of this mineral and those of laurionite and fiedlerite; for laurionite gives no figure at all through the large face, and fiedlerite a biaxial figure which is not central.

Although the crystals measured were invariably twinned, the principal index of refraction in the direction perpendicular to the plane of symmetry could be determined in the usual manner. Using the prism formed by the faces $a(100)$ $k(\bar{4}01)$, three values were obtained for sodium light: 2·1445, 2·1447 and 2·1497, the mean of which is 2·1463.

(c) The chemical composition.

By means of the optical criterion given above, as much material as possible (0·1360 gram) was carefully picked out for the chemical analysis which was made by Mr. G. T. Prior. The composition agrees closely with that of laurionite—

	Paralaurionite.	Calculated PbClOH.
Pb ...	78·1 ...	79·7
Cl ...	14·9 ...	13·7
H_2O ...	3·4 ...	3·5
O (by diff.) ...	(3·6) ...	3·1
	100·0	100·0

Water is given off at about 180° C.: it is given off at 142° C. in the case of laurionite. The specific gravity (the weight of 1 cc.) is 6·05 at 18° C.

---

[1] Cf. Liebisch, *Physikalische Krystallographie*, Leipzig, 1891, Tafel VI, Figs. 4, 5, and 6.

Digitized by Google

Communications from the Oxford Mineralogical Laboratory.

Mineralogical Notes: Zinc-Blende; Galena; Pyrites; Lead.

By Prof. H. A. Miers, M.A., F.R.S.,

With Analyses by E. G. J. Hartley, B.A.

[Read Nov. 15th, 1898.]

1. *Zinc Blende with Metallic Lustre.*

A SPECIMEN in the University Museum consists of black tetrahedral blende, exhibiting perfect *metallic* lustre; indeed, the brilliant steely cleavage surfaces of the mineral and its metallic tarnish raised a doubt whether it could really be blende; but in very thin fragments viewed by transmitted light it is seen to be brown in colour.

The crystals are bright tetrahedra, a combination of {111} {1$\bar{1}$1} {110} {211} {2$\bar{1}$1}, and are accompanied by chalcopyrite, quartz and kaolin, on a matrix of chloritic vein-quartz containing iron pyrites. The locality of the specimen is not known, but it may well be Cornish.

Mr. E. G. J. Hartley analysed the mineral at my request with the object of ascertaining whether the metallic appearance is due to any unusual constituent. He obtained the following numbers:—

				Calculated for 5ZnS.FeS.
Zn	...	56·88	...	56·72
Fe	...	9·29	...	9·77
Cu	...	·07		
Mn	...	trace		
S	...	33·42	...	33·51
		99·61		100·00

Thus the mineral is a ferriferous zinc-blende corresponding almost exactly to the formula 5ZnS.FeS. The specific gravity estimated on 1·1314 gram is about 3·8.

The lustre is so unlike that of ordinary blende, that the question arises whether the union of ZnS and FeS in *molecular* proportions has not given rise to a mineral having properties distinct from those of a mere isomorphous mixture of the two sulphides.

Digitized by Google

2. *Zinciferous Galena.*

A small specimen of galena in the University Museum consists of brilliant cubes of galena disposed on quartz and associated with a little iron pyrites. The corners of the cubes are truncated by faces of the octahedron, which exhibit a very marked laminar structure.

The following analysis by Mr. Hartley shows that the mineral contains nearly 5 per cent. of zinc, although no traces of zinc-blende are observed when the crystals are finely crushed.

				Calculated for 4PbS.ZnS.
Pb	...	78·47	...	78·63
Zn	...	4·97	...	6·17
Fe	...	·67		
S	...	15·07	...	15·20
		99·18		100·00

The mineral therefore corresponds to the formula 4PbS.(Zn,Fe)S, in which, as in the preceding mineral, the proportions are molecular.

Many examples of zinciferous galena have been previously recorded, but in none of them has the substance been in such distinct crystals as in the present instance, and there is no certainty that they were not mixtures of galena and blende.

The present specimen is stated to be from Bingham, Salt Lake, Utah.

Through the kindness of Professor J. E. Talmage I have received a specimen of the massive galena from the same locality. This specimen contains no zinc, but only a small proportion of iron.

3. *A tetartohedral (?) crystal of Pyrites.*

A specimen of pyrites which has the appearance of the well known specimens from Gilpin Co., Colorado, and is probably from that locality, presents the peculiarity shown diagrammatically in Fig. 1.

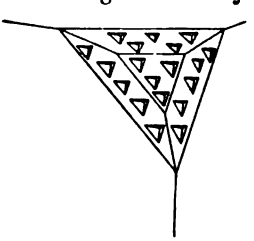


Fig. 1.

Digitized by Google

The crystals are brilliant combinations of cube with the pentagonal dodecahedron {210}, and are associated with a little galena and blende. The corners of the cubes are rough, and present at first sight the aspect of a rounded etched surface. Closer inspection shows that the cube corners are really replaced by brilliant faces of {111} and {211}, but that these faces are penetrated by a number of parallel and minute sub-individuals whose corners project so as to constitute a drusy surface. These latter corners are simply formed by cube faces without a trace of the octahedron or of {211}. They are clearly not etched planes, nor are they merely small individuals deposited on the large cubes; for they emerge from the latter, and near the edges they can be traced continuously into it.

I would suggest that these are completely interpenetrant twinned crystals of tetartohedral habit in which an unmodified cube corner of one individual protrudes through each tetrahedron face of its companion. They are in that case analogous to the twins of sodium chlorate, or to those growths of ullmannite which I have previously described as evidence of the tetartohedral nature of that member of the pyrites group (*Min. Mag.* 1891, IX. 211).

Further evidence of twinning is afforded by very minute facets barely discernible on the edges of the small projecting cubes; these are faces of {120} supplementary to those on the adjacent part of the large crystal. The same twinning probably accounts for the presence of the two supplementary forms {210} {120} on the crystals from the same locality described by E. F. Ayres (*American Journ. Sci.* 1889, 37, 236).

4. *On some Crystal Forms of Lead: a study in crystal-measurement.*

[Read June 21st, 1898.]

WHEN a piece of cast lead is subjected to the action of dilute nitric acid, it becomes etched in such a way that the surface is divided into drusy patches, each of which has a silky appearance, and can be distinguished from its neighbours when a bright light falls upon it, since numerous points on each patch reflect light together.

This indicates that each patch belongs to one crystalline individual, and the etching proves the whole mass to have a coarsely crystalline structure like a meteoric iron or a nugget of gold. In the specimen to which this note more particularly refers, the patches (*i.e.* the constituent crystal grains) are about 3 mm. in diameter.

Examined under the microscope, the drusy surface is seen to consist of minute crystals, having in some patches a rectangular, and in others a hexagonal outline. Sometimes crystals of hexagonal contour have three

Digitized by Google

ribs radiating from the centre to the corners of the hexagon, suggestive of a skeletal growth.

In some of the patches the drusy surface is seen to consist of numbers of microscopic, but very perfect and brilliant crystals, which are ranged in parallel position. Some of these present the appearance of cubes or square prisms, but others have the aspect of hexagonal prisms terminated by pyramidal facets. The latter are so perfect that at first sight one can hardly believe them to be crystals of lead, and their appearance is so different from that of the crystals of square outline that they might well be supposed to be a hexagonal modification. On the other hand, it seems more probable that the crystalline structure of the lead is cubic throughout, and that the hexagonal outlines are due to the etched surface being nearly perpendicular to a cube diagonal, while the square outlines belong to those parts which are nearly perpendicular to a cube axis. According to this view each patch is a single crystal grain of lead on which "sub-individuals" have been developed by the action of the solvent, their habit being due to the orientation of the parent crystal and the direction in which it is intersected by the surface.

The hexagonal prisms sometimes project, either perpendicularly or obliquely, from what appears to be clearly a rough etched surface of the lead, although they are themselves perfectly smooth and bright; and Mr. A. Dick, from whom I received the specimen to which this description particularly applies, is of opinion that these crystals have not been developed by the mere etching away of surrounding material, but are deposited as lead crystals from the solvent. They certainly present a very different appearance from some negative cubes which have evidently been etched into the lead, and from some cubic outlines which remain between these negative crystals. According to this view the minute sub-individuals deposited on each patch become orientated in parallel position by the crystal on which they are laid down.

However this may be, the hexagonal prisms are crystals of the most perfect nature, with lustrous facets, and their true symmetry can only be determined by measurement of their angles.

The crystals are far too small, and in any case too soft, to be isolated and measured in the ordinary way; and indeed it seemed hopeless to attempt any goniometrical measurement of such material,

However, by taking advantage of the fact that each patch consists of a considerable number of *parallel* crystals, and by using the two-circle or theodolite-goniometer, I have been able to measure the crystals with complete success and to identify their faces.

Digitized by Google

A small etched button of the lead which I received from Mr. Dick, having been mounted on the theodolite goniometer, it was possible to make a series of measurements, taking account only of the light reflected from one of the small drusy patches. By reason of the large number of parallel facets yielding each reflection, it was easy to obtain an image from faces which were almost invisible; and although the images, as is usually the case with those reflected by a number of parallel crystals, were not perfectly sharp, they were quite reliable to three or four minutes.

Another series of measurements could then be made upon another of the drusy patches and compared with the first. The lead button can be adjusted to any convenient position at the beginning of each such series.

As a result of the measurements it was found that the hexagonal prisms have the form of Fig. 3, and that they are really a cubic combination similar to those represented in Fig. 2, but elongated along the ditrigonal axis.

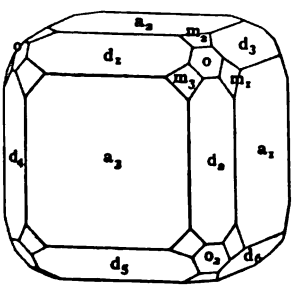


FIG. 2.

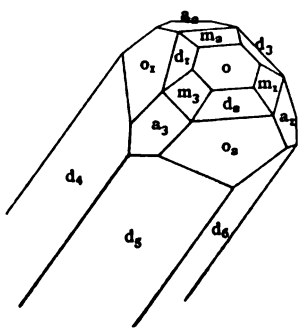


FIG. 3.

The following are the readings obtained from a single patch, A being the reading on the horizontal circle, and B the reading on the vertical circle for each face; the basal plane *o* having been adjusted perpendicular to the axis of the vertical circle, so that the image from *o* remains centred as the vertical circle B is rotated.

Digitized by Google

		A.		B.
o	...	161°11	...	...
a_1	...	286 23	...	30°35′
m_1	...	131 36	...	30 35
d_1	...	196 24	...	210 58
o_1	...	231 40	...	210 30
a_2	...	215 56	...	270 31
m_2	...	190 43	...	270 38
d_2	...	125 58	...	90 38
o_2	...	90 39	...	90 38
a_3	...	106 29	...	150 36
m_3	...	131 42	...	150 49
d_3		196 25	...	330 13
d_4	...	71 6	...	180 35
d_5	...	71 0	...	120 35

In the following table the readings are reduced to 0°0′ (A) for the face o, and to 0°0′ (B) for the zone $a\,m\,o$.

		A.		B.
o	...	0° 0′	...	...
a_1	...	54 48	...	0° 5′
m_1	...	29 45	...	0 5
d_1	...	35 13	...	0 28 + 180°
o_1	...	70 29	...	0 0 + 180
a_2	...	54 45	...	60 1 + 180
m_2	...	29 32	...	60 8 + 180
d_2	...	35 13	...	60 8
o_2	...	70 32	...	60 8
a_3	.	55 10	...	120 6
m_3	...	29 39	...	120 19
d_3	...	35 14	...	119 43 + 180
d_4	...	90 5	...	150 5
d_5	...	90 11	...	90 5

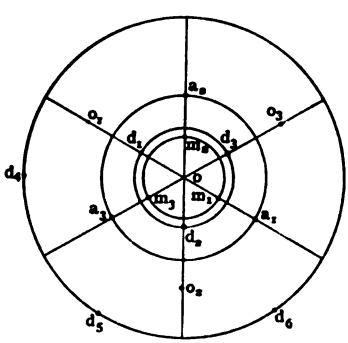


FIG. 4.

Digitized by Google

From these numbers it may be seen that the faces occupy the position shown in the accompanying stereographic projection, Fig. 4, and belong to the following forms :—

$$a\{100\},\ o\{111\},\ d\{110\},\ n\{811\},$$

for which the theoretical readings on circle A are

$$54°44',\ 70°31',\ 35°16',\ 29°30'.$$

The above observations conclusively establish the cubic nature of these apparently hexagonal crystals of lead.

This communication shows how it is possible under certain conditions to obtain accurate measurements from faces almost too small to be visible, and belonging to a crystal which cannot be isolated. Such measurements can only be made by means of the theodolite goniometer.

The method could possibly be applied to other cases of parallel crystals forming a drusy surface, such as those etched upon meteorites and gold nuggets.

Digitized by Google

Note on the Crystals of Lead described in the preceding communication.

By Allan Dick.

As Professor Miers has quoted my opinion of the manner in which the lead crystals measured by him were formed, I may state the circumstances under which I gave the opinion.

The etched button of lead was prepared by Mr. J. G. Stead, of Middlesborough, in the course of an investigation into the structure of metals, part of which has been published by the Iron and Steel Institute. The button was sent to a mutual friend, who it was hoped would be able to state exactly the crystalline system to which the hexagons belonged. My friend, finding himself unable to do so, asked me to look at the button, as he knew I had worked at lead during many years. I did so, and recognised the appearance which corroded lead presents under the microscope. As some of the patches showed the minute hexagons rather larger than usual, and well placed for inspection, I thought it a good opportunity to learn more about the hexagons than I knew, for they had long been a puzzle to me. With Mr. Stead's approval I sent the button to Professor Miers, with a request that he would, if possible, measure and describe the crystals, which he has fortunately been able to do.

When lead approaching purity, such as that used in white lead making, is cast in a mould so that the upper surface is exposed to the air, it is found that that surface presents different appearances according to the purity of the lead, the temperature of the mould, and other conditions. The surface is broken up into patches, each of which is a separate crystal. In large castings each crystal may be from an inch to many inches in diameter, and when the skin is stripped from such a solidifying mass it is seen that the skeletal octahedra beneath are differently orientated in each patch. When the facets of the octahedra are parallel to the surface, brilliant large flat planes result. When the points of the octahedra are at right angles to the surface, it presents a fern-like appearance. When the former are corroded, an hexagonal wreckage is produced, whereas the latter gives rise to a rectangular wreckage. The skeletal octahedra are not always parallel or at right angles to the surface, but sometimes variously inclined, giving rise to hexagonal or rectangular wreckage variously inclined.

Digitized by Google

In nearly pure lead the hexagonal and rectangular etched surfaces are of brilliant lustre, but never, so far as I have seen, present any pyramidal facets. When the lead is rather impure, the surfaces of the etched (negative) crystals are dull and pitted. But on either quality of lead brilliant crystals with pyramidal facets, such as Professor Miers has figured, may be formed, and I think arise from the redeposition of lead on the etched surfaces under certain circumstances.

Any one desiring to see these crystals may easily produce them as follows. Cast a small round button of nearly pure lead so that it resembles a flattened drop. Place it in an egg-cup flat side downwards, and so that there may be only a small space between the bottom of the button and the bottom of the cup. Fill the cup half full of water containing from 5 per cent. to 10 per cent. of nitric acid, and leave the whole at rest from 24 to 48 hours. Wash with water and examine under the microscope, using an inch or a half-inch object glass. Generally, but not always, a few patches of the brilliant crystals will be seen amongst the general patches of rectangular and hexagonal forms. They are easily recognised by their greater brilliance and more complex forms. I have many times seen the corners of cubes modified as Professor Miers has shown in Fig. 2. It is very interesting to see how the cubes and hexagons are related to one another.

I think these brilliant crystals, cubic and hexagonal, are formed by the electrolytic deposition of metal which is being dissolved away from the upper surface, exposed to nitric acid and nitrate of lead, and re-deposited on parts of the lower surface where the lead is exposed only to nitrate of lead; it is an instance of the deposition of metal from a circuit of two liquids and one metal.

I have seen very beautiful examples of the cubic and hexagonal structure in the "blue lead" resulting from the manufacture of white lead by the "Dutch process." In such cases the white lead detached from the blue lead, if examined under the microscope, shows perfect casts of the hexagonal and cubic structure of the corroded surface of the blue lead. They look like opaque crystals of white lead, but are only casts of the corroded surfaces.

Beautifully etched surfaces of lead may be formed by heating cast lead in a rather strong solution of nitrate of lead, and such surfaces generally have the rectangular and hexagonal structure more coarsely developed than I have otherwise seen it. It can then be seen by a $\frac{1}{4}$ inch hand lens.

Digitized by Google

Communications from the Oxford Mineralogical Laboratory.

On the constitution of the mineral Arsenates and Phosphates.

By E. G. J. Hartley, B.A.

[Read June 21st, 1898.]

Part I.—*Chalcophyllite.*

THIS mineral was originally described as a hydrated copper-arsenate. Analyses of copper-arsenate are given as far back as 1801 by Vauquelin (*Journ. des Mines*, 1801, X. 562), and by Chenevix in the *Philosophical Transactions* (for 1801); but at this early date the analyses seem to refer partly to chalcophyllite and partly to olivenite.

Subsequently analyses have been published by Hermann, Damour and Church—(1) Hermann, *Journ. prakt. Chem.* 1844, XXXIII. 294; (2) Damour, *Ann. Chem. Phys.* 1845, XIII. 413; (3) Church, *Journ. Chem. Soc.*, 1870, VIII, 168.

	As_2O_5	P_2O_5	CuO	H_2O	Al_2O_3	FeO	
Hermann	17·51	undet.	44·45	31·19	3·93	2·92	=100
Damour (i)	19·35	1·29	52·92	23·94	1·80	—	= 99·3
„ (ii)	21·27	1·56	52·30	22·58	2·13	—	= 99·84
Church	15·54	—	46·1	(31·75)	5·97	—	= 99·4

From the last analysis Church deduced the formula—

$$8CuO.Al_2O_3.As_2O_5.24H_2O \text{ (or } 25H_2O).$$

In Hermann's and Damour's analyses the water was determined by loss of weight on heating the mineral, but this method is not satisfactory, as there is always the risk of minerals of this class losing arsenic on ignition. Church only estimated the water by difference. It therefore seemed advisable to make a fresh analysis of this mineral, especially with a view to estimating the water directly.

Though the exact locality of the mineral used for analysis is uncertain, the specimens were undoubtedly old Cornish specimens, and consisted of fine pale emerald-green crystals implanted on massive cuprite, and associated with quartz and traces of malachite and chessylite.

The portion taken for analysis was very carefully picked under the microscope, and consisted entirely of clear crystals, free from any inclu-

Digitized by Google

sions except a few minute black specks which were visible in some of the crystals.

Although the mineral loses nearly 18 per cent. of water at 100 C., no change in its optical properties was observed when the crystals were heated on a sheet of mica supported over the stage of a polarising microscope until a considerable temperature was reached, when they suddenly became opaque and cracked. Under these circumstances they appeared nearly black, but when examined in sufficiently thin flakes they were seen to be yellow and devoid of double refraction. No further change was produced when the fragments were immersed in water.

A qualitative analysis was made to see if iron or phosphoric acid were present, but neither of these substances was found.

Analysis.

The water was determined by heating a weighed portion of the mineral in a porcelain boat in a hard glass tube, and collecting the water given off in a weighed calcium chloride tube.

To prevent any arsenious oxide from passing over with the water, a layer of about two inches of a mixture of lead oxide and dioxide was interposed between the boat and the calcium chloride tube. This layer was heated by means of a broad luminous flame kept about 1 inch below the tube, and it has been found that in this way all arsenic is kept back while the water passes over.

With regard to the rest of the analysis, the arsenic acid was reduced with sulphurous acid, and the copper and arsenic precipitated together in a strongly acid solution with sulphuretted hydrogen. The arsenic sulphide was dissolved out as far as possible by sodium sulphide, and the copper was redissolved and reprecipitated in one case as oxide, and in the other as sulphide, and weighed as such.

The alumina was estimated in the filtrate from the copper and arsenic by evaporating and precipitating with ammonia.

The arsenic acid was estimated in a separate portion by direct precipitation with magnesia mixture, a small quantity of tartaric acid having been added to prevent the simultaneous precipitation of alumina or copper. The percentages thus found from the analysis showed a deficit of about 7 per cent.; it was then found that sulphuric acid is present as a constituent of this mineral in such a proportion as exactly to account for the deficit. It is remarkable that this constituent has been entirely overlooked by previous analysts.

The analytical numbers are as follows:—

Digitized by Google

·2192 grm. lost at 100 C. ·0393 grm. $H_2O = 17{\cdot}93$ %
and gave further on ignition ·0233 ,, $H_2O = 10{\cdot}63$ % } 28·56 % H_2O

·2271 grm. gave	·0643	H_2O	corresponding to	28·31 %	H_2O
·2003 ,,	·0559	H_2O	,,	27·91 ,,	H_2O
·3436 ,,	·1582	CuO	,,	46·04 ,,	CuO
	·0163	Al_2O_3	,,	4.74 ,,	Al_2O_3
·2632 ,,	·1206	Cu_2S	,,	45·82 ,,	CuO
	·0125	Al_2O_3	,,	4.74 ,,	Al_2O_3
·2828 ,,	·0559	$Mg_2As_2O_7$	,,	14·66 ,,	As_2O_5
·2409 ,,	·0463	$Mg_2As_2O_7$	,,	14·26 ,,	As_2O_5
·3652 ,,	·0759	$BaSO_4$	,,	7·13 ,,	SO_3
·2423 ,,	·0491	$BaSO_4$	,,	6·96 ,,	SO_3

Taking the mean of these results the following numbers are obtained :—

(Water lost at 100 C., 17·93.)

Total	H_2O	28·26
	CuO	45·93
	Al_2O_3	4·74
	As_2O_5	14·46
	SO_3	7·04
		100·43

It seems impossible to deduce a simple formula for the mineral from these numbers, which give the following molecular ratios for the different constituents :—

H_2O	1·57
CuO	·58
Al_2O_3	·046
As_2O_5	·062
SO_3	·088

It is therefore desirable that further analyses of chalcophyllite from some other localities should be made, with a view to finding variations in the proportions of some of the constituents which might throw light on the true constitution of this mineral.

The specimens of chalcophyllite used in the preceding investigation were from the mineral collection in the Oxford University Museum, and the analyses were made in the laboratory of the Mineralogical Department.

Digitized by Google

REVIEWS.

A Text-book of Mineralogy, with an extended treatise on Crystallography and Physical Mineralogy. By Edward Salisbury Dana. New Edition, entirely re-written and enlarged. Large 8vo, 593 pp., over 1,000 figs., and a coloured plate. New York and London, 1898.

Prof. E. S. Dana's text-book of Mineralogy in scope occupies an intermediate position between elementary books in which little or no attempt is made to deal adequately with the crystallographic and optical branches of the subject, and such a work of reference as Dana's *System of Mineralogy*. The want of such a text-book in English has of late years been increasingly felt owing to the advances made in the science, especially in crystallographic and optical methods of investigation. This new edition has been entirely re-written and brought up to date, and should go a long way towards satisfying this want. The first part of the book, occupying 144 pages, is devoted to crystallography. According to the degree of symmetry they exhibit, crystals are divided into the now-accepted thirty-two groups. These are classified under the six systems, the group in each system possessing the highest degree of symmetry being called the normal group. In the introductory articles is a brief account of molecular networks or point systems, according to which these groups receive their theoretical explanation. This subject has been engaging the attention of mineralogists so much of late that we are inclined to regret that the author has not felt able to devote more space to its consideration. An intelligible summary in English of this subject, similar to that given by Groth in the last edition of his *Physikalische Krystallographie* would be very desirable at the present time.

The second part of the book, dealing with physical mineralogy, occupies 94 pages, and is mainly taken up with the optical characters of crystals. A useful feature in this as in other parts of the book is the list, at the end of each main section, of references to important papers on the subject discussed in the section. In the articles treating of optical instruments and methods, mention might have been made of the Dick microscope which has proved so eminently serviceable in the optical examination of minerals.

Digitized by Google

The whole subject of the optical properties of crystals is very fully treated, and it is shown how these can be deduced from the index-ellipsoid or indicatrix of Fletcher, the axes of which are proportional to constants capable of direct measurement, viz. the refractive indices α, β, γ, where $\alpha < \beta < \gamma$.

It is, therefore, all the more puzzling to find a later article headed "Axes of elasticity," in which it is stated that "these axes of elasticity are of great convenience in describing the optical properties of crystals, *and it is hence necessary to make frequent use of them.*" These, in fact, are the axes which, under the new name of "ether-axes," the author uses in the descriptive part of the book. He mentions, it is true, that these axes of elasticity "have the direction of the three ellipsoidal axes" (the axes of the indicatrix), but he does not clearly point out to the student that it is the *a* (α)-axis of the indicatrix which corresponds to the *a* (a)-axis of elasticity and so on, and accordingly that old formulæ, expressed in the language of elasticity, can be at once translated into the language of the indicatrix by substituting 'axis of indicatrix' for 'axis of elasticity,' *e.g.*, a positive biaxial crystal is one in which the *c* (γ)-axis of the indicatrix as well as the *c* (c)-axis of elasticity is the acute bisectrix. To the mineralogist the fact is of little concern that, regarded as an axis of the indicatrix, the *c*-axis is the greatest, whereas regarded as an axis of elasticity it is the least. The axes of elasticity most often employed are not those of Fresnel's ellipsoid of elasticity, which is identical in form with the indicatrix, but of its polar reciprocal. They are usually denoted by the letters a, b, c, where a > b > c, whereas the axes of the indicatrix being proportional to the refractive indices are generally denoted by α, β, γ where $\alpha < \beta < \gamma$. It is probably on this account, and to obviate the necessity of altering the lettering of old diagrams, &c., that the author has elected to retain the old axes of elasticity under their new name of ether-axes. We cannot help thinking that this is quite a needless complication, which might have been avoided by denoting the axes of the indicatrix by the letters a, b, c. The result of this would be that old formulæ and diagrams, illustrating the relation of the crystallographic to the light-axes, would need no alteration: it would be only necessary to remember, when any question might arise as to their relative magnitude, that in the case of the indicatrix a < b < c.

To the third part of the book, treating of Chemical Mineralogy, only thirty pages are devoted. The elementary principles of chemistry, as applied to minerals, are briefly but clearly explained, and reference is made to the periodic law. The subject of isomorphism and the con-

Digitized by Google

nection between chemical composition and crystalline form receives rather brief treatment. A short account is given of the blowpipe examination of minerals, but for this and kindred subjects the reader is referred to Brush's *Manual of Determinative Mineralogy*, a new edition of which, under the editorship of Prof. Penfield, has just appeared.

The fourth part of the book, on descriptive mineralogy, is "essentially an abridgment of the Sixth Edition of Dana's *System of Mineralogy*," as prepared by the author. In the case of the more important minerals, however, useful paragraphs have been added in which are given the distinguishing characters which serve to separate the species from others with which it might be confounded.

At the end of the book are appendices, one treating of the drawing of crystals and of projections, and the other containing tables of minerals, arranged according to crystal system, specific gravity, &c., which should be very serviceable for determinative purposes.

The book is not altogether free from printer's errors. In the preface the Oxford professor of mineralogy is referred to as Prof. Miers of Cambridge, on pp. 28 and 31 some of the indices of the faces are incorrect, on p. 158 the heavy liquid methylene iodide is referred to as methyl iodide, a very different substance.

As an excellent text-book of Mineralogy, and the only one in English containing a full treatment of the crystallographic and optical principles of the science according to the most recent methods of investigation, the book should meet with wide acceptance. G. T. P.

Geology for Beginners. By W. W. Watts, M.A., F.G.S., Assistant-Professor in Geology at the Mason University College, Birmingham. 8vo, 352 pp., 310 figs. London, 1898.

This excellent little text-book of geology forms one of Macmillan's Elementary Science Series. Although intended for use in preparation for the elementary stages of the Science and Art examination, it has none of the objectionable features of the ordinary cram-book.

The treatment is necessarily of an elementary character, but for its size the book contains a really marvellous amount of information arranged in admirable fashion to meet the needs of the student.

The general "plan of work" as set forth by the author in the first chapter explains well the excellent mode of treatment adopted and the general aim of the book. First, common rocks are pulled to pieces, and studied at home. Then are noted their mode of occurrence and appear-

Digitized by Google

ance in the field. After which the various geological changes taking place at the present time are explained, so that the student may duly appreciate the way in which rivers carve out their valleys and seas tear down their cliffs, and deposit the relics, in the one case in deltas and river basins, and in the other on the sea-bed. From the study of what is actually occurring at the present day the student is then taught to deduce what has happened in the past and to "find out how the rocks succeed one another, and what points in the history of life or geography each one yields." At the end of the book, after the different geological systems have been described, is an instructive and interesting chapter on the origin of landscape, and finally a rather short chapter on economic geology.

A prominent feature of the book is the number and excellence of the illustrations. As is well known, the author, as secretary to a British Association Committee, has been zealous in directing the attention of geologists to the advisability of collecting and preserving photographic records of interesting geological features. The number of reproductions of such photographs taken by various observers, which adorn the pages of his book, seem to show that the author has begun to reap some advantage from his labours. Many of the other illustrations have been taken from Zittel's *Grundzüge der Paläontologie.*

The book appears to be remarkably free from printer's errors. The following are a few points we have noted to which exception may be taken. The granite figured on p. 9 is not a very typical example of granitic structure. The chemical composition of a felspar is not very well expressed by the statement on p. 36, that it is "a compound of two substances, known respectively as silicate of potash and silicate of alumina." On p. 122, trimetric is used instead of the more usual orthorhombic. On p. 126, magnetite is described as crystallising in dodecahedra, whereas if only one habit of the crystals is mentioned octohedra are far more common. On page 130, chlorite is referred to the hexagonal system. On p. 168, tachylyte is spelt 'tachylite.'

These, however, are but very minor points, and do not seriously detract from the value of a book which, in our opinion, is by far the best elementary treatise on geology which has appeared within recent years.

G. T. P.

Manual of Determinative Mineralogy, with an introduction on Blowpipe Analysis. By George J. Brush. Revised and enlarged with entirely new tables for the identification of minerals by Samuel L. Penfield.

Digitized by Google

New York (John Wiley and Sons), London (Chapman and Hall, Ld., 1898). Large 8vo, 312 pp., 375 figs.

The first edition of this book, by Prof. G. J. Brush, appeared in 1874, and the present is the 15th edition. This fact alone testifies to the great popularity of the work.

In 1896, a first instalment of the present edition was issued, with the introductory chapters entirely re-written by Professor Penfield, but with the old tables, and was reviewed in this Magazine (vol. xi. 219). The work now re-appears in a complete form, as a new book, with the determinative tables revised, and with a new chapter of 84 pages on the Physical Properties of Minerals. This chapter is the simplest and most intelligible summary of the principles of crystallography that has yet been given to the elementary student, and is a very noteworthy feature of the book; especially satisfactory are the diagrams by which the symmetry of the 32 crystalline types are illustrated and the order of their symmetry axes depicted.

In the very complete tables for the determination of mineral species which constitute the latter half of the book, the following classification is adopted:—I. Minerals with metallic lustre; II. Minerals without metallic lustre. Within each of these classes the species are grouped by their fusibility. In class I. the fusible minerals are further distinguished by blowpipe reactions as arsenic, selenium, tellurium and antimony compounds, and sulphides, while the infusible minerals include iron and manganese compounds. In class II. the fusible compounds include (1) those which yield globules of silver, lead, bismuth, antimony and copper; (2) the iron compounds, which become magnetic; (3) certain arsenates, phosphates, borates, silicates, and salts of the alkali, and alkali-earth metals. The infusible compounds comprise the remainder.

Practically all the known species are included in these tables, but the more common are printed in conspicuous type. It is stated in the preface that all the tests have been carefully verified, and many have been devised specially for the present work. The real value of the book can only be ascertained by its practical use. We may confidently expect that it will be found to fulfil all the requirements of the student.

Should Professor Penfield feel able to include a chapter on the optical examination of crystals in a future edition without increasing the book to an inordinate size, it will become a complete handbook, with the aid of which a skilful student should be able to identify any known mineral, including even the rarer species.

Digitized by Google

The Boy Mineral Collectors. By Jay G. Kelley, M.E. 362 pp. (Philadelphia: J. B. Lippencott Company, 1899).

This is a story, in conversational form, of the doings of two boys while on a visit to their mining uncle in Colorado. Instead of profitably spending their time in collecting minerals in the open, they spend most of it talking in the library. There are popular chapters on "Metals of great value," in which vanadium is quoted at 2,240 dollars per pound; "A lesson on pearls and rubies"; "A chat on silver and diamonds," &c. Information on any one subject is much scattered, and is not always quite accurate; the names of minerals are sometimes incorrectly spelt. As a story the book is a failure.

Digitized by Google

OBITUARY.

Andreas Arzruni.

ANDREAS ARZRUNI, born at Moscow on November 27th, 1847, was the last male descendant of the ancient Armenian family Arzrunier, which, from the 11th century until the conquest of Armenia by the Turks in the 16th century, held the Principality of Waspurakan, of which Van was the capital.

After a short stay at the St. Petersburg University, Arzruni migrated to Heidelberg, where he studied chemistry under Bunsen. He then (1872) for a time assisted Prof. Groth at Strassburg, and in 1877 became Privatdocent in the Berlin University. From 1880 to 1883 he acted as Assistant in the Mineralogical Museum at Berlin, of which Websky was then director. In 1883 he was appointed Extraordinary Professor at Breslau, and a year later Ordinary Professor of Mineralogy in the Technical High School at Aachen, which post he held till the last. In the winter of 1895-6, while on a visit of inspection to the gold fields of British Guiana, he had an attack of fever, and this, together with consumption, compelled him to spend the last year or so in sanatoria in Switzerland and on the Rhine. He died on September 22nd, 1898, and was buried at Tiflis, his Armenian home.

Arzruni was the author of some 50 papers published in various scientific journals, including Russian and Italian. Notices of a few of these have appeared in the *Mineralogical Magazine*. His first paper, published in 1871, was on a chemical subject; others in ethnological journals related to prehistoric stone implements, especially those of jade and jadeite; and several were descriptive of the minerals and rocks collected on his journeys in the southern Urals. Two minerals, groddeckite and utahite, were first described by him, and before his illness he was investigating a new Chilian mineral, the description of which still remains unpublished. His best known work, however, is the *Physikalische Chemie der Krystalle* (1893), this being a subject which he had especially studied; and the book displays evidence of an immense amount of bibliographical research. (A more detailed account of his life is to be found in *Zeits. prakt. Geol.*, 1898, 446-8.)

Digitized by Google

ABSTRACTS.

Scottish Minerals. The third part of Vol. VII. of the *Trans. Edinburgh Geol. Soc.* 1897, contains several papers of mineralogical and petrological interest. Many of them are illustrated with plates.

H. M. Cadell (p. 173) has a note on the occurrence of vivianite in an old lake bed at Cauldhame, near Linlithgow. The mineral incrusts bone and pieces of stone, or is mingled with earth and peat.

J. G. Goodchild (pp. 201-2) describes the minerals of the Hilderston silver mines, Linlithgow. They include calcite, barytes, argentiferous galena, and the rarer minerals niccolite, annabergite and erythrite.

J. Currie (pp. 223-9) describes various secondary minerals from the volcanic rocks of Ben More in Mull. Scolecite occurs as radiated groups of crystals sometimes 10 cm. long. Epidote is found in good crystals. Dark green celadonite is very abundant, whilst saponite is rare. Heulandite, stilbite and prehnite are also found. To account for the abundance and unusual associations of these minerals, pneumatolytic action is assumed. The same author (pp. 252-3) gives a crystallographic description of apophyllite from Kimberley, S. Africa, a figure of a Scotch crystal being added for comparison.

M. F. Heddle (pp. 241-3) figures crystals of analcite from the Boylestone quarry near Barrhead in Renfrewshire. Besides {211}, there are small faces of the forms {100}, {332}, {*h l l*} and two hexakisoctahedra, possibly {543} and {421}, but no measurements are given. The crystals show good corrosion figures, and are not composite in structure. They are small and colourless, and occur with prehnite, thomsonite, and large crystals of white opaque analcite. A second paper (pp. 265-7) by the late Prof. Heddle is on the crystalline form of riebeckite from Ailsa Craig: two plates, illustrating the various forms observed, are given. L. J. S.

Mossite, and the crystalline form of Skogbölite. (W. C. Brögger, *Vidensk. Skrifter, I. Math.-nat. Klasse, Kristiania*, 1897, No. 7, pp. 1-19).—The new mineral, mossite, occurs with yttrotantalite and columbite in a pegmatite vein at Berg in the parish of Råde, near Moss, in Norway. The tetragonal crystals are black with sub-metallic lustre;

Digitized by Google

they are usually twinned on (101) and elongated in the direction of the pyramid edge [111, 1$\bar{1}$1], then having the appearance of simple orthorhombic crystals of prismatic habit. Analysis by G. Thesen gives the formula $FeNb_2O_6.FeTa_2O_6$. Sp. gr. = 6·45.

In the following isodimorphous group the tetragonal members are homœomorphous with rutile, xenotime, etc., and the orthorhombic with brookite.

		Tetragonal.	Axis *c*.	Orthorhombic.
$Fe(Ta,Nb)_2O_6$	...	Tapiolite	0 6525.	Tantalite.
$Fe(Nb,Ta)_2O_6$	...	Mossite	0·6438.	Columbite.

The so-called tantalite from Tammela in Finland (= skogbölite), which was described as orthorhombic with a form more or less closely related to that of columbite, is now shown to be identical with tapiolite, the crystals being really tetragonal and twinned like mossite. The skogbölite forms:

r(490), *a*(100), *μ*(011), *b*(010), *q*(031), *n*(016), *v*(322), *p*(111), *o*(211),

as given in Dana's *Mineralogy*, p. 736, are the tapiolite forms:

(111) (010) (100) (101) (301) (30$\bar{1}$) (110) (320) (230)

respectively. Twinning on *b*(010) was stated to be common in skogbölite, but this, being a plane of symmetry in an orthorhombic crystal could not be a twin plane; it is the twin plane 101 of tapiolite.

C. H. Warren (*Amer. Journ. Sci.* 1898, VI, 121) has described simple and twinned crystals of tapiolite from the felspar quarries at Topsham, Maine. The twinned crystals have the same orthorhombic habit as mossite. L. J. S.

Heavy Liquid for separating Minerals. (W. Muthmann, *Zeits. Kryst. Min.* 1898, XXX. 73-4).—Acetylene tetrabromide, $CHBr_2-CHBr_2$, which may be easily prepared by passing acetylene into bromine, has sp. gr. = 3·0011 at 6°, and refractive index = 1·6479 for sodium light. It is stable, and does not darken on exposure to light; it has no action on metallic minerals, and is miscible in all proportions with benzene, ether, etc.: and it is less than one-tenth the cost of methylene iodide (sp. gr. = 3.35). L. J. S.

Dehydration of Analcite. (Georges Friedel, *Bull. Soc. franç. Min.* 1896, XIX. 363-390).—The amount of water given off by analcite at a definite temperature is dependent on the tension of aqueous vapour in the air. It is therefore necessary when determining the amount of water

Digitized by Google

lost on heating zeolites to observe the tension of aqueous vapour as well as the temperature. Constant results are only obtained when the powdered mineral is heated in a rapid current of dry air. If, after dry air has been used, a current of moist air be passed over the heated mineral, there is, in spite of the elevated temperature, an absorption of water, and to expel this again with the same tension of aqueous vapour a higher temperature is required. Equilibrium in such cases is more rapidly established the higher the temperature; that is, water is more slowly re-absorbed the lower the temperature. L. J. S.

Constitution of Mispickel. (F. W. Starke, H. L. Shock and E. F. Smith, *Journ. Amer. Chem. Soc.* 1897, XIX. 948-952; compare abstr. XI. 105).—Mispickel (FeAsS) has been considered to be FeS_2 with the sulphur partly replaced by As'', or $FeAs_2$ containing S'''. In attempting to determine the true constitution of the mineral, the following experiments were made.

When heated in hydrogen only sulphur is expelled. Under similar conditions pyrites and marcasite lose half their sulphur. Heating with copper sulphate solution in sealed tubes, or with ammonium chloride, showed the presence of much ferrous iron and As''', and only a little ferric iron. The amount of ferrous iron was determined to be about 30½ per cent. by heating the mineral in a current of dry hydrogen chloride. Since mispickel contains 34·35 per cent. Fe, this leaves about 4 per cent. for ferric iron.

The formula of mispickel is therefore provisionally given as 14Fe''As'''S. 2Fe'''As'''S. Experiments to determine the molecular weight by observing the influence of mispickel on the solidification point of alloys were without result. L. J. S.

Krennerite from Cripple Creek, Colorado. (A. H. Chester, *Amer. Journ. Sci.* 1898, V. 375-377).—This mineral has previously only been known from Nagyag in Transylvania. It has now been found as bright crystals associated with quartz and pyrites at Cripple Creek. The colour is pale yellowish bronze, but on the perfect basal cleavage it is tin-white. Measurements by Penfield are given of the orthorhombic crystals, and analysis by W. S. Myers gives the formula $AuTe_2$; only 0·45 per cent. of silver is present.

The compound $(Au,Ag)Te_2$ appears to be trimorphous, being orthorhombic in krennerite, monoclinic in sylvanite, and probably anorthic in calaverite (Abstr. XI. 235), though the last two may be identical, only differing in the amount of silver present. L. J. S.

Digitized by Google

Orthoclase as a gangue mineral in fissure veins. (W. Lindgren, *Amer. Journ. Sci.* 1898, V. 418-420).—A review is given of the few recorded occurrences of felspars in mineral veins, and a new occurrence is described. A vein on Florida Mtn. in the Silver City mining district of southern Idaho contains pyrites, copper pyrites and argentite, with a gangue of quartz and orthoclase; it is richest in orthoclase where it traverses granite, there is less where it intersects rhyolite, and none where it intersects basalt. The orthoclase occurs as large irregular milk-white grains intergrown with vein-quartz and enclosing pyrites and argentite, or as crystals coating quartz and lining crevices in the altered granite adjoining the vein. The crystals are of the adularia habit, with the forms $m\{110\}$ and $x\{\bar{1}01\}$. An analysis by Hillebrand is given.

That orthoclase has been formed artificially in the wet way supports the idea that this vein of orthoclase has been formed by aqueous deposition. Its comparatively rare occurrence may possibly be due to the frequent presence of carbonated thermal waters in mineral veins. L. J. S.

Rhodolite, a new Garnet. (W. E. Hidden and J. H. Pratt, *Amer. Journ. Sci.* 1898, V. 294-296).—A "rose garnet," named rhodolite on account of its rose-red or rhododendron-red colour, occurs as rolled pebbles in the gravels of a brook called Mason's Branch, in Macon Co., North Carolina. It is unusually free from internal flaws and inclusions, and forms a fine gem-stone, which in brilliancy resembles the green demantoid of the Urals. Sp. gr. = 3·837. Analysis gives the formula, $2Mg_3Al_2(SiO_4)_3 + Fe_3Al_2(SiO_4)_3$, *i.e.* two molecules of pyrope with one of almandine. L. J. S.

Clinohedrite, a new mineral. (S. L. Penfield and H. W. Foote, *Amer. Journ. Sci.* 1898, V. 289-293).—This is associated with willemite, garnet, phlogopite, axinite and datolite at the Trotter mine, Franklin, New Jersey. The monoclinic crystals are interesting on account of their hemihedrism, there being a plane of symmetry but no axis of symmetry (domatic class). Owing to the absence of parallel faces (except $b(010)$) the crystals present a peculiar inclined-faced character, hence the name clinohedrite; $a : b : c = 0·6826 : 1 : 0·3226$; $\beta = 76°4'$. There is a perfect cleavage parallel to $b(010)$. H = 5·5; sp. gr. = 3·33. The crystals are pyroelectric; they are often transparent, and the colour varies from amethystine to nearly colourless or white. The optic axial plane and obtuse bisectrix are perpendicular to $b(010)$. Formula $H_2ZnCaSiO_5$, or, as the water is only expelled at a high temperature, $(ZnOH)(CaOH)SiO_3$.

Digitized by Google

This is analogous to the hemimorphite formula $H_2Zn_2SiO_5$, or $(ZnOH)_2SiO_3$. [The name clinohedrite is preoccupied.] L. J. S.

Melanotekite from New Mexico. (C. H. Warren, *Amer. Journ. Sci.* 1898, VI. 116).—This mineral, previously only known from Sweden, has recently been found at Hillsboro in New Mexico. It has a dark brown to almost black colour, and gives an ochre-yellow streak resembling that of limonite. Cavities are lined with minute orthorhombic crystals of prismatic habit; $a : b : c = 0{\cdot}6338 : 1 : 0{\cdot}9126$. Analyses give the formula $2Fe_2O_3.3PbO.3SiO_2$. Sp. gr. = 5·854. The formula previously given for melanotekite is $Fe_2O_3.2PbO.2SiO_2$, and for the isomorphous kentrolite, $Mn_2O_3.2PbO.2SiO_2$. The four earlier analyses of these two new minerals show considerable variations, and three of them agree better with the new formula than with the old. L. J. S.

Quartz-alunite Rock. (H. W. Turner, *Amer. Journ. Sci.* 1898, V. 424).—Three sharp buttes, called Tres Cerritos, in Mariposa Co., California, are composed of augite-porphyrite-tuffs and clay-slate which have been subjected to solfataric action. Most of the altered rocks are light brown, and resemble quartzite in appearance. Under the microscope they are seen to consist of quartz and a mineral which was shown by analysis, made on material separated by a heavy liquid, to be alunite, $(K,Na)_2O.3Al_2O_3.4SO_3.6H_2O$. L. J. S.

Phenakite from Kragerö, Norway. (H. Bäckström, *Geol. För. Förh.* 1898, XX. 295-303; and *Zeits. Kryst. Min.* 1898, XXX. 352-356).—Large crystals of phenakite have recently been found in a felspar quarry near Kragerö. They were at first taken to be "rock crystal." They are colourless to grey, and usually clouded, and are sometimes several decimeters in length. The habit is prismatic, and the terminal faces only very rarely show the tetartohedral development so characteristic of phenakite, the apparent symmetry being as a rule that of calcite. The common forms are $a\{10\bar{1}\}$, $r\{100\}$ and $s\{20\bar{1}\}$, also $d\{110\}$, $p\{210\}$, $m\{11\bar{1}\}$, $z\{\bar{1}22\}$, &c., but the common phenakite form $x\{21\bar{1}\}$ is very rare.

C. H. Warren (*Amer. Journ. Sci.* 1898, VI. 119) has described still larger crystals, measuring up to 12 inches in diameter and weighing 28 lbs., from Greenwood, Maine. These are, however, only pseudomorphs of quartz after phenakite.

Phenakite has also been recently recorded from the granite of Striegau in Silesia (C. Hintze, *Zeits. Kryst. Min.* 1897, XXVIII. 174). L. J. S.

Digitized by Google

Cohenite in telluric Irons from Greenland. (E. Cohen, *Meddelelser om Grönland*, 1897, XV. 293-304).—A carbide of iron, present to the extent of 52 per cent. in the nickel-iron of Niakornak near Jakobshavn in N. Greenland, consists of greyish-black crystalline aggregates with good cleavage. Sp. gr. = 7·5124; analysis gives the formula Fe_3C with the iron partly replaced by nickel and cobalt. Shepard's chalypite, Fe_3C, from the same iron is probably identical with this. An analysis is also given (*Ann. k.k. naturhist. Hofmus.* 1897, XII. 58) of a similar carbide of iron from the well-known Ovifak iron of Disko Island. Both of these are no doubt identical with the meteoric cohenite. L. J. S.

Crystalline Structure of Gold Nuggets. (A. Liversidge, *Journ. Roy. Soc. N. S. Wales*, 1897, XXXI. 70-79; and *Trans. Chem. Soc.* 1897, LXXI. 1125-1131).—In a previous paper (Abstr. XI. 101) the author held the view that gold nuggets have been derived from gold reefs, rather than that they have been deposited *in situ* from solution. In the latter case the structure of the nuggets would be concentric. With the view of testing this, polished sections of gold nuggets have been etched, but no trace of concentric structure was observed. The 16 fine plates illustrating the paper show that the structure of nuggets and ingots of gold platinum and tin is that of an irregular aggregate of interlocking crystals, often of considerable size. L. J. S.

Bornite from the Tyrol. (E. Weinschenk, *Zeits. Kryst. Min.* 1896, XXVI. 392; A. Heimerl, *Tsch. Min. Mitth.* 1897, XVII. 289; C. Klein, *Sitz.-ber. Akad. Berlin*, 1898, 885, 521).—Large isolated crystals of bornite have recently been found in a gold vein on Frossnitz-Alpe in the Gross-Venediger, associated with calcite, albite, gold, chlorite and limonite. They are distorted icositetrahedra with rough, striated faces, and a thin coating of malachite. The forms are {211}, {322}, {533} and {100}. The largest [now in the British Museum] measures 5·6 × 4·2 × 4·2 cm. along the cubic axes. L. J. S.

The so-called anomalous etched figures on monoclinic crystals, especially on Colemanite. (H. Baumhauer, *Zeits. Kryst. Min.* 1898, XXX. 97-117). —After a discussion of his own and other work on the results of etching crystals of diopside, the author describes the figures produced on the cleavage face (010) of colemanite by etching with very dilute acids. Hydrochloric acid was chiefly employed, but similar results were given by sulphuric acid. Three kinds of figures were observed:—

Digitized by Google

(α) flat; symmetry monoclinic holohedral.

(β) deeper, varying with the strength of the solvent, but no simple relation found; symmetry also monoclinic holohedral.

(γ) which seem to be developed from the (β) figures; *asymmetric.*

The figures (γ) on the faces (010) and (0$\bar{1}$0) are complementary, *i.e.* one set is the reflection of the other. Also a plane through the edges (110):(1$\bar{1}$0) and ($\bar{1}$10):($\bar{1}\bar{1}$0) divides the crystal into two parts which are symmetrical with respect to (010). There are on (010) two sets I. and II., and on (0$\bar{1}$0) another pair III. and IV., of which I. and IV., II. and III. are parallel, while I. and III., II. and IV. are symmetrical with respect to (010). To determine the structure several plates parallel to (010) were sliced out of the same crystal. Similar results were obtained on all the plates, and it was always found that whenever two plates had been together in the crystal, the figures on the sides, which had formerly been in contact, were identical point for point. Sometimes a (γ) figure would correspond to a (β) figure, which led the author to suppose that the (γ) figures are developed from the (β) figures.

The faces of the forms (100), (001), ($\bar{2}$01) and (110) were also etched. The resulting figures gave monoclinic holohedral symmetry, except some on (100) and (001); but the observations were not sufficiently numerous to determine if the symmetry was the same as in the case of (010).

Since neither careful goniometric measurements of crystals (afterwards etched) nor optical observations reveal any anomalies, and also since holohedral figures accompany the (γ) figures, the author concludes that the symmetry of the crystal is monoclinic and holohedral, but that of the molecule asymmetric. G. F. H. S.

Modifications of Granitic Magma in contact with Limestone. (A. Lacroix, *Comptes rendus*, 1896, CXXIII, 1021-1023).—At the peak of Braceil, in Orlu, Ariège, the granite of Quérigut is in contact with a thick sedimentary series, consisting of schists with thick limestone bands. The schist and limestone have been largely absorbed by the granitic magma, and fragments of these rocks are enclosed in the granite. The granite in contact with the extensively corroded limestone has undergone considerable alterations; by loss of quartz and felspar and development of hornblende and mica, and lastly olivine, it becomes progressively more basic and passes to hornblende granite, quartz diorite, mica diorite, hornblendite, and finally to hornblende peridotite; this being an almost complete series of granular eruptive rocks. Sometimes enstatite is developed, and norites, with or without olivine, result. The plagio-

Digitized by Google

clases, oligoclase to anorthite, are zoned and much corroded, indicating great variations in the composition of the magma. The green or brown hornblende occurs in large individuals, and, in the more basic rocks, encloses the other minerals. L. J. S.

The Influence of the temperature of dehydration on the 'weathering figures' of Gypsum. [L. Sohncke, *Zeits. Kryst. Min.*, XXX, 1, 1898]. The author states that, in common with other later observers (*Blasius, Zeits. Kryst.*, X, 236, 1885, and Weiss, *Zeits. d. d. geol. Ges.*, XXIX, 211, 1877, and *Zeits. Kryst.*, III, 97) he has been unable to obtain the elliptical 'weathering figures' (*Verwitterungsflecke*) which were found by Pape (*Pogg. Ann.*, CXXXV, 6, 1868) to be produced on the faces of a crystal of gypsum, heated to near 100° C in an air bath, and which corresponded in the position of their axes to an "ellipsoid of weathering." The figures obtained by the author on cleavage surfaces agree with those described by Weiss (*loc. cit.*), and have in general a rectangular outline, whose sides are roughly parallel and perpendicular to the vertical axis. They are traversed by two straight lines nearly coinciding with the diagonals of the rectangle. The upper and lower of the four sectors into which the figure is thus divided show striæ nearly parallel to the vertical axis, while the other two sectors show in addition a striation parallel to the fibrous fracture.

The author has investigated the effect of the temperature used on the form of the figures, and finds that with increase of temperature the ratio of the horizontal to the vertical diameter diminishes.[1]

The direction of the vertical striae makes an angle of some 8° with the vertical axis in the acute angle of the axes (β). The angle between the diagonals is about 81°, their bisectrix lying in the acute angle β, and making 4½° with the vertical. One of the diagonals appears to correspond with the mean axis of thermal expansion. H. L. B.

---

[1] Further, while at low temperatures (105°), the vertical sides of the figure show an outward curvature, the horizontal edges being straight, at higher temperatures the vertical edges are straight while the horizontal ones are rounded or even bent, giving the figure the appearance of a hexagon, and the outline of the figures alters somewhat.

Digitized by Google

Digitized by Google

THE MINERALOGICAL MAGAZINE

AND

JOURNAL

OF THE

MINERALOGICAL SOCIETY.

No. 56. OCTOBER, 1899. Vol. XII.

On a new mode of occurrence of Ruby in North Carolina.

By Prof. J. W. Judd, C.B., LL.D., F R.S., V.P.G.S., and W. E. Hidden, F.G.S.

With Crystallographic Notes by Dr. J. H. Pratt.

[Read Jan. 31st, 1899.]

PARTS of the State of North Carolina, with adjoining areas in South Carolina and Georgia, have long been known to mineralogists and geologists as among the most interesting of corundum localities; and the researches of the late Dr. Genth, Col. Joseph Willcox, Mr. J. Volney Lewis and many other authors have done much to make clear the mode of occurrence and associations of corundum in this area and in the great corundiferous belt stretching along the line of the Appalachian crystalline area from Alabama in the south to Maine in the north. Quite recently Dr. J. H. Pratt has published a very interesting and admirable discussion of "The origin of the Corundum associated with the Peridotites of North Carolina."[1]

But of the existence in any part of this area, or indeed in any part of the continent of America, of the red transparent variety of the mineral, which the term Ruby is properly restricted, there appears to have

[1] *Amer. Journ. Sci.* 4th Ser. Vol. VI. 1898, p. 49.

Digitized by Google

been no knowledge till about 15 years ago (1884). Nor has there been, as yet, any notice published of the discovery in any scientific journal or magazine, unless we except the brief mention made in the Annual Statistical volumes entitled *Mineral Resources of the United States*, published under the auspices of the U.S. Geological Survey.[1]

Some few additional notes upon this interesting occurrence have been published, including press notices, but nothing of a strictly scientific character. We may state that one of us has during the past five years frequently visited the scene of this discovery, and that from time to time we have conjointly examined many of the cut specimens and natural crystals of the rubies from the Cowee district of North Carolina, and that in our opinion their beauty and colour appear to be in no way inferior to those from the Mogok district of Burma.

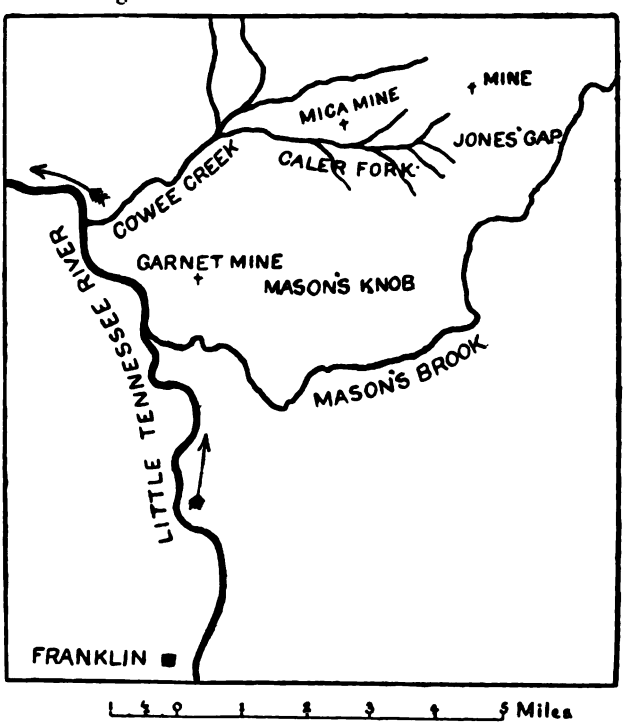


FIG. 1.—Sketch Map of the district in which Ruby and Rhodolite are found.

[1] 15th Annual Report, 1893–94, U.S. Geol. Survey, Volume on *Mineral Resources of the United States* (Washington, 1894), p. 693.
Ibid. 16th Annual Report, Part IV. p. 599.
Ibid. 17th Annual Report, Part III. p. 905.

Digitized by Google

As the material in which these rubies were found appeared so strikingly similar to the alluvium and gravel in which the Burma rubies are obtained, it at one time seemed highly probable that when the thick masses of superficial and detrital material could be sunk through, the rock in which the rubies would be found *in situ* would prove to be a limestone like that of Burma. This expectation was strengthened by the finding in the gravels of corundum crystals of similar form, with almost precisely the same association of minerals as occurs in Burma.

The district in which these interesting discoveries have been made is situated in the State of North Carolina and in the County of Macon, rather more than 20 miles from the borders of Georgia. Some five or six miles below the town of Franklin the Little Tennessee River receives on its right or eastern side two affluents, the Cowee Creek with its tributary the Caler Fork, and the Mason Branch. It is the tract between these two brooks, some 10 square miles in area, which has proved to be of such exceptional mineralogical interest, and has yielded a very large number of remarkable species and varieties of minerals.

The bottoms of the valleys of this mountain district are about 2,500 feet above the sea-level, and the various hills ("knobs") in and immediately around it rise to the height of from 3,000 to 3,500 feet; but at no great distance to the west there occurs much higher ground (the Nantahaleh Mountains) up to 5,000 and 5,500 feet.

In 1896 the district was visited and examined by Mr. C. Barrington Brown, who had made the examination for the British Government of the well-known ruby district of Mogok in Burma. He found that the country was one of gneissose rocks, the gneiss often containing garnets and corundum,[1] not of gem quality, and that this mass of gneissose rocks is probably traversed, like that of Burma, by great dykes of pegmatite and more basic rocks, for blocks of these materials are abundantly scattered through the gravels of the district.

Garnets are so abundant in some of the rocks of the district that mines have been opened to work the rocks for abrasive materials. In some of the pegmatites the crystals of muscovite are so well developed that several "mica mines" have been opened. There are other mines which have been worked for copper with some prospects of success; while, as we shall see in the sequel, gold, monazite, and sperrylite (the rare

[1] The corundum in these gneissose rocks usually occurs in long hexagonal prisms with basal planes, but no other forms, and the mineral nearly always exhibits purplish tints.

Digitized by Google

arsenide of platinum) have been obtained in the alluvial deposits which are so extensively present in this region.

Although only a few miles away from Corundum Hill, Buck Creek, Ellijay, and other famous corundum localities, where, as shown by Lewis, Pratt, and other authors, corundum is found in the intrusive dunites, near their junction with the crystalline schists of the district, *no* olivine rocks, or serpentines derived from them, have been found in the immediate neighbourhood of the new ruby locality.

Neither have limestone rocks been found in close proximity to the alluvia containing these fine rubies. In fact, the nearest point at which any limestone bands have been found is about eight miles away. Here the bands consist of a "calciphyre," not unlike some of those found in Burma, and, like them, containing many silicates, such as wollastonite, scapolite, pyroxenes, hornblendes, biotite, &c., with graphite, pyrrhotite, and many other minerals.

When the alluvium and the gravels below them (the latter being from 2 to 10 feet in thickness) are penetrated, they are often found to rest on a soft rock known to American petrologists as "saprolite," which is the result of the weathering in place of basic silicate rocks. This "saprolitic" rock can often be pierced to considerable depths, without the undecomposed rocks from which it has been derived being reached.

Washing and microscopic examination of the saprolitic material shows that it is largely made up of scales of various hydrous silicates, among which damourite and other hydrous micas, with margarites and other clintonites, are very conspicuous. The unaltered minerals present consist of fibrolite, staurolite, and some other silicates, with menaccanite, rutile, monazite, spinel, and considerable quantities of garnet (including the rhodolite variety) and corundum (of various shapes and tints), and minute quantities of gold and sperrylite.

The trial shafts and gravel-washing operations which have been undertaken in this district, with a view to discover the extent and nature of the valuable minerals, have shown that at depths of 35 feet and upwards the saprolitic rock includes fragments, and is seen to pass into various basic rocks. These include hornblende-eclogite (garnet-amphibolite of some authors), amphibolite, and a basic hornblendic gneiss containing labradorite and perhaps anorthite. The full description of these rocks is deferred until the exploration now going on shall have more fully displayed their relations in the field, and have enabled more satisfactory and less altered specimens to be obtained. It is as yet uncertain whether these rocks occur as dykes or as alternating interfoliated masses in the crystalline series.

Digitized by Google

The great band of basic and garnet-bearing rocks, in the decomposed materials derived from which are found the rubies, is traversed by a remarkable series of slickensides. Four parallel slides have been exposed at one place in the workings, the direction being generally N. 75° E. Continuous slickensides of 70 feet in length, and of unknown depth, can be seen, and, with some interruptions, they can be traced for several hundreds of feet east and west. It is probably the breaking up of these rock-masses by faulting, leading to the ready influx of water (which so readily attacks the basic silicates of which the rock is composed), that has led to their reduction to the saprolitic condition.

Scattered through the saprolitic material are nuclei of eclogite and amphibolite, which have to some extent escaped disintegration, and in the centre of the mass lenticles of pure hornblende rock are found. In one place one of these lenticles of hornblende rock is nearly a rod in width, and in nearly all cases the saprolite adjoining these lenticles of hornblende rock is seen to contain, very abundantly, either corundum or more commonly the pseudomorphs after corundum.

The corundum occurring in these rocks varies in colour from ruby red through various shades of pink to white and nearly colourless varieties. Many of the red crystals exhibit the beautiful so-called pigeon's-blood tint, which is so much admired in the gems from Burma, and the colours seen in the Cowee-Creek stones with the dichroscope are almost identical with those exhibited by the stones from Burma. As at Mogok, Sagyin, and other Burmese localities, the rubies of very fine tint are mingled with others of lighter or darker shades, and with varieties which exhibit more or less of a purplish tint mingled with the red.

The Cowee-Creek rubies very frequently contain inclusions of various kinds. Sometimes these are extremely minute ("silk" of jewellers), and give rise to a cloudiness ("sheen") in the polished gems; at other times minute reniform masses of clear red rutile and black menaccanite occur, and mar their beauty. The included crystals of garnet, to be hereafter more particularly noticed, do not greatly destroy the transparency or impair the fine character of the stones. Some specimens have been found, however, from which gems of fair size could be cut, quite free from inclusions and of fine colour and transparency.

The clearest crystals of the Cowee-Creek rubies nearly always show the tabular habit which Lagorio regards as characteristic of the varieties of corundum that have separated from an igneous magma. Indeed, so common is this form, that any long prismatic crystals found with them may be suspected of having been derived from the surrounding gneisses,

Digitized by Google

in which such forms occur sometimes abundantly. The most common combination of forms is that shown in the accompanying drawing, which has been made by Professor S. L. Penfield, of the Sheffield Scientific School, Yale University.

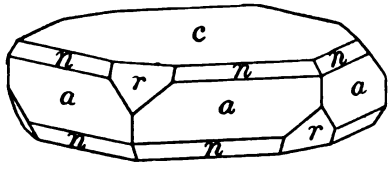


Fig. 2.

Common form of Corundum Crystals at Cowee-Creek.

In an appendix to this paper Dr. Pratt has drawn and described some of the chief types of corundum crystals obtained in the Cowee district, and it will be found interesting to compare these with the combinations of forms which the same author has described as occurring at Yogo Gulch, Montana,[1] and which Dr. Max Bauer has described from Burma.[2]

The corundum crystals, whether ruby-red or pink in colour, occur in "nests" and "bands," and also in what appear to have once been empty spaces in the rocks, either amphibolite, or eclogite, or hornblendic gneiss. The spaces, when the corundum is pale-coloured, appear to have been filled up with felspathic material; but when the corundum is of a ruby-red colour, the surrounding space is filled up with chloritic material.

Corundum is not, however, confined wholly to these bands, which were once druse-like cavities in the rock, but it often happens that the mineral, sometimes red and transparent, is found in the midst of the rock.

One respect in which the corundum of Cowee-Creek resembles that of Burma is in the readiness with which it seems to have undergone pseudomorphous change by hydration followed by combination of the resulting diaspore with surrounding silicates. The pseudomorphous material often retains the shape and occupies the place where crystals of corundum were originally firmly embedded in the hard matrix. Often only a thin flake of corundum remains in the midst of a mass of alteration products to tell the character and colour of what was once a large crystal.

It is surprising to see the positive evidence of the former existence of hundreds of pounds weight of ruby and other varieties of corundum, where, to-day, only a few ounces of fragments or flakes remain.

---

[1] *Amer. Journ. Sci.* 4th Ser. Vol. IV. (1897), pp. 424–428.

[2] *Neues Jahrb. für Min.* &c. 1896, Bd. II. pp. 197–238.

Digitized by Google

The most notable of the minerals associated with the rubies and other forms of corundum at Cowee-Creek is garnet, and this garnet is remarkable for its colour and beauty as a gem-stone. The colour is unlike that either of pyrope or almandine, and lacks that depth and intensity which usually makes garnets such dark-looking stones, especially by artificial light. These garnets, on the contrary, have a peculiar and very beautiful tint, combined with a transparency and brilliancy which is more striking in artificial light than in ordinary daylight. From the resemblance of its colour (a pale rosy tint inclining to purple) to that of certain roses and rhododendrons, this variety of garnet has received the name of "rhodolite."[1]

The rhodolite usually occurs in water-worn fragments, mixed with corundum and the other minerals found in the "saprolitic" rock and in the gravels of the district. Only minute crystals, occurring as inclusions, have as yet been found, and these are sometimes rhombic-dodecahedra and at other times trapezohedra (icositetrahedra). The garnets show the same tendency to alteration as the corundum, and pseudomorphs of the mineral abound, as is the case in Burma.

The association of rubies and rhodolite in this district is not only proved by their constant occurrence together in the saprolitic material and in the gravels, but we find indisputable evidence that the garnets have crystallised first, and that the corundum has solidified afterwards, and has enclosed the garnets partially or entirely in its crystals. Some

---

[1] The rhodolite of the Cowee-Creek and Mason's Branch district has been recently carefully studied by Dr. Pratt in conjunction with one of us.

"On Rhodolite, a new variety of Garnet," by W. E. Hidden and J. H. Pratt. *Amer. Journ. Sci.* 4th Ser. Vol. V. (1898), pp. 294–296. [Abstr. *Min. Mag.* xii, 133.]

Analysis shows that it has the following composition:—

Silica	41·59
Alumina	23·13
Ferric Oxide	1·90
Ferrous Oxide	15·55
Magnesia	17·23
Lime	·92
	100·32

This analysis corresponds, almost exactly, to a combination of two molecules of the magnesium-aluminium garnet (pyrope) with one molecule of a ferrous iron-aluminium garnet (almandine). There is considerable variation in the tint of rhodolite, the approach being sometimes towards the pyrope colours, at others towards the almandine. Probably the proportion of the two molecules is by no means constant. In spite of the preponderance of the pyrope molecule, as shown by analysis, an examination of the absorption bands of rhodolite, which was kindly made for us by Professor Church, F.R.S., shows that it gives the same characteristic spectrum as is found in almandine.

Digitized by Google

of the ruby crystals bear impressions, of which a mould can be taken in wax, and these impressions give with a goniometer the angles of the rhombic-dodecahedron or the trapezohedron. In some cases clear crystals of ruby corundum have been broken open, and minute garnets actually taken out of the middle of them. In other cases fractured surfaces of the basic rocks show corundum surrounding and enclosing garnet crystals, while in other cases cut gems of ruby can be seen to have in their midst a garnet crystal.

So far as our experience goes, this enclosure of garnet by corundum is peculiar to this special Cowee district, and serves to distinguish the corundum found in it from that occurring in any of the tracts where the mineral occurs in peridotites (dunite, &c.), or at the junction of peridotites with the crystalline schists.

This remarkable association of garnet and corundum is well illustrated by a drawing (Fig. 3) made upon the spot by one of us from a specimen that was of too friable a character to bear removal intact. Although the sketch is to a certain extent ideal, it faithfully represents the undoubted relations of the garnets and corundum as seen in one very interesting specimen.

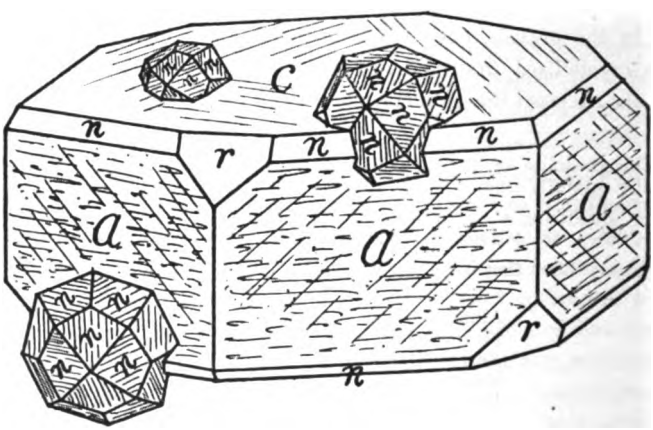


FIG. 3.

Corundum enclosing crystals of Garnet.

Specimens are occasionally found in the district which appear to be pseudomorphs of quartz after dodecahedral garnets.

Spinel, which is so constantly associated with the corundum (ruby) of Burma, is rare in the American locality. The fine red spinels, so similar

Digitized by Google

in tint to the rubies themselves, and so conspicuous in the Burma localities, appear to be entirely wanting in the North-Carolina area. Three varieties of spinel, namely, picotite, gahnite, and chromite (the last being rare), have been found both in the alluvial deposits and *in situ* in the basic rocks.

Of minerals specially characteristic of materials formed by contact metamorphism, the following have been found:—Sillimanite (fibrolite), cyanite, staurolite (often very clear and gem-like in character), and cordierite (or iolite, colourless and without dichroism).

The chief ferro-magnesian silicates are hornblende (a variety rich in soda) and bronzite (in clear transparent masses suitable for gems).

Among the accompanying minerals are zircon (with the variety cyrtolite), monazite (the macroscopic brown and green varieties appear to be rare, but a minute brilliant yellow granular variety with only 0·03 per cent. of thoria abounds), rutile and menaccanite.

Among metallic minerals the chief are pyrite, chalcopyrite, nickeliferous pyrrhotite, blende, sperrylite, and gold.[1]

Conclusions.

Corundum has now been shown to occur in North Carolina and the adjoining States in three different forms: —

(1) In the ordinary crystalline schists of the district, long prismatic crystals, usually of gray, pink and blue tints, occur.

(2) In the peridotites (dunites, &c.), intrusive in the crystalline schists, and especially in and near the zones of contact, crystals, some of very great size, and of great variety of colour, but seldom or never clear and translucent, are found.

(3) In certain garnet-bearing basic rocks at Cowee-Creek, small tabular and short prismatic crystals are abundant, and these very frequently exhibit the transparency and colour of the true ruby.

Dr. Pratt, in his recent discussion on the second of these modes of occurrence of corundum, has shown grounds for concluding that the alumina of the corundum was in these cases originally dissolved in the fused basic magma of the peridotites, and that crystals of corundum separated from that magma in the manner which has been illustrated by the interesting experiments of Morozewicz.[2]

[1] For fuller details concerning these accompanying minerals with analyses consult a paper "On the Associated Minerals of Rhodolite," by W. E. Hidden and J. H. Pratt. *Amer. Journ. Sci.* 4th Ser. Vol. VI. (1898), pp. 463–468.

[2] *Zeits. Kryst.* Vol. XXIV. (1895), p. 281, and *Tscherm. Min. und Petrog. Mitt.* (*Neue Folge*), Vol. XVIII. (1898), pp. 1–90, 105–240.

Digitized by Google

The tabular form of the crystals of corundum has been shown by Lagorio[1] in his well-known memoir on the subject to be characteristic of corundum found in igneous rocks. And this conclusion has been supported by the researches of Professor L. V. Pirsson and Dr. Pratt.[2]

If we compare the forms figured by Dr. Pratt in the appendix to this paper with those described by him from Yogo Gulch, the resemblance will be seen to be very striking. But it may at first sight appear that it is impossible to ascribe an igneous origin to corundum enclosing a mineral with so much lower a fusing point as that of garnet.

A little consideration will, however, show that this objection has little validity. The temperature at which alumina is dissolved in a mixture of silicates has no necessary connection with the fusing point of alumina itself. That the magma from which these basic rocks consolidated was fluid at a temperature lower than the fusing point of the garnets, or at all events that the rock was in a state of aqueo-igneous fusion at a lower temperature, is evidenced by the condition of the beautifully crystallised garnets scattered through the basic rocks. At such temperatures, according to the experiments of Morozewicz, alumina may be largely dissolved in the basic fluid magma, and may slowly crystallise out from it. In this way we may conceive of the garnets being enclosed in a later formed corundum.

There are many points of resemblance between the association of minerals and the forms of crystallisation of the Cowee-Creek rubies and those of Burma. This will become apparent if we compare the figures now published with those given by Prof. Max Bauer of the Burma rubies.[3]

In considering the association of minerals described by Prof. Max Bauer in his paper it should be remembered that the material on which that author worked came almost entirely from Sagyin, while those described by Mr. Barrington Brown and one of us were derived from the Mogok district, nearly 60 miles away. There is reason for concluding that the associations of minerals in these two districts of Burma present some interesting points of difference.

Although, at first sight, the matrix of the Burma rubies (a crystalline

---

[1] *Zeits. Kryst.* Vol. XXIV. (1895), p. 285.

[2] "Corundum-bearing Rock from Yogo Gulch, Montana," by L. V. Pirsson. *Amer. Journ. Sci.* 4th Ser. Vol. IV. (1897), p. 421.

"Crystallography of the Montana Sapphires," by J. H. Pratt. *Ibid.* p. 424.

[3] *Neues Jahrb. Min.* &c., 1896, Bd. II. Taf. VII.

Digitized by Google

limestone) may seem so different from that of the rubies of Cowee-Creek (an amphibolite with garnets, and sometimes with a basic felspar), yet a connection may still be shown to exist between the two cases. One of us has brought forward evidence to show[1] that the limestone of Burma has been formed by the slow alteration of a lime-felspar. Whether the corundum pre-existed in the highly-basic felspathic rock, however, or was formed at a later stage, there is no positive evidence to show. But the idea of its existence in the silicate rock originally is supported by the wonderfully corroded state of the corundum crystals.

The magma giving rise to pyroxene gneisses and granulites of Burma may not have differed greatly in composition from that giving rise to the amphibolites, eclogites, and basic gneiss of North Carolina; and, in either case, corundum may have been formed by the separation of dissolved alumina. The great promise which is held out by the fine colour and quality of many of the ruby crystals from this new locality would seem to warrant a continuance of the prospecting work lately inaugurated there, and it is to be hoped that the interesting problem of *the true origin of these rubies* may be definitely settled when the explorations on Cowee-Creek shall have furnished fuller data and more conclusive evidence concerning the primary condition of the associated minerals and the nature and relations of the rocks of the district.

[1] *Phil. Trans.* Vol. 187A (1896), pp. 151–228.

Digitized by Google

On the Crystallography of the Rubies from Macon County, North Carolina.

By Dr. J. H. Pratt.

THE ruby crystals from the Cowee Valley, Macon County, North Carolina, show a very wide variation in their development. Although many of the crystals are so striated that no crystallographic measurements were possible on the reflecting goniometer, the faces were readily identified by means of the contact goniometer. On some of the crystals the faces were bright and smooth, making them well adapted for measurement on the reflecting goniometer. The following references are to Plate I.

Among the crystals examined there were two common habits noticed, one, as shown in Figs. 1 and 2, which is a combination of the base $c(0001)$ and the unit rhombohedron $(10\bar{1}1)$; the other, represented by Figs. 3 to 6, where the prism $a(11\bar{2}0)$ is very prominently developed. The rhombohedral crystals vary from those where the base is largely developed, having a diameter of 12 mm., while the rhombohedron is only 1·5 mm., to some (Fig. 1) which have the base and rhombohedron more equally developed. The majority of these crystals have, however, the base more largely developed, thus giving the crystals a flat tabular appearance. This rhombohedral development is very similar to that of the sapphires from Yogo Gulch, Montana, described by the author.[1]

On some of the prismatic crystals the prism reaches a length of nearly 15 mm. in the direction of the *c* axis, and has the rhombohedron but slightly developed (Fig. 3), while on others the prism is very short and the rhombohedron sometimes is wanting, as represented in Figs. 4 and 5.

Another habit of these crystals is shown in Figs. 7 and 8. There the pyramid $n(22\bar{4}3)$ is well developed. This face was identified by means of the contact goniometer, the measurements approximating closely to the calculated angles. The usual form of these crystals is shown in Fig. 7, where the faces $c(0001)$, $a(11\bar{2}0)$, $r(10\bar{1}1)$ and $n(22\bar{4}3)$ are nearly equally developed. On some of the crystals the prism is very prominent, being 8 mm. in length in the direction of the *c* axis, while the pyramid is only 1·5 mm. On others the pyramid is only very slightly developed. A few crystals were examined which showed only the presence of the base, the rhombohedron and the pyramid, as represented in Fig. 8. The crystals,

[1] *Amer. Journ. Sci.* Vol. IV. 1897, p. 424.

Digitized by Google

measuring up to 7 mm. in diameter, were doubly terminated and nearly perfect in their development.

The crystals represented by Figure 7 are similar to those described by Max Bauer[1] from the Burma district, and are almost identical in form with a sapphire crystal figured by the author, from Emerald Bar, Canon Ferry, Magher County, Montana.

Although both the basal and rhombohedral planes are very often striated, it is only on the basal planes that these are sharp and distinct and can be measured. The striations are parallel to the three intersections of the base c with the rhombohedron r, as shown in Fig. 5.

A very common development that was noticed in nearly all the flat rhombohedral crystals, and on many of the prismatic crystals, is a repeated growth on the basal plane of the rhombohedron $r(10\bar{1}1)$ and the base $c(0001)$, as represented in Figs. 1 and 6.

To better illustrate the variation in these growths, a series of figures (9 to 14) have been drawn in basal projection. In Figs. 9 and 10, which represent the more common development of these repeated growths, there is but one secondary rhombohedron and base, which sometimes has one of its rhombohedron faces a continuation of one of the rhombohedron faces of the crystal. Figs. 11 and 12 represent repeated growths, the faces of which are separate and distinct from each other and from the faces of the main crystal. In the crystals represented by Fig. 12, when the secondary growths are but slightly developed the basal plane of the crystal has the appearance of being striated with triangular markings. In Figs. 13 and 14 there are represented a series of growths where a number of the rhombohedral faces coincide.

Some of the pyramidal crystals (Figs. 7 and 8) also showed the development of the secondary growth of rhombohedron and base.

The thickness of the rhombohedron of the secondary growth varies from those that are so thin that they appear like striations to some that are 2 mm. thick.

This same style of development has been described by Bauer[2] as occurring in the Burma rubies, and it has also been described by the author[3] as occurring on the Montana sapphires.

A few crystals were observed on which there was a secondary growth parallel to the prism $(1\bar{1}20)$.

[1] *Neues Jahrb. Min.* 1896, II. 197.

[2] *Loc. cit.* p. 209.

[3] *Amer. J. Sci.* Vol IV. 1897, p. 424.

Digitized by Google

Communications from the Oxford Mineralogical Laboratory.

On the constitution of the natural Arsenates and Phosphates.

By E. G. J. Hartley, B.A.

[Read Jan. 31st, 1899.]

Part II.—*Pharmacosiderite.*

THIS mineral, which until now has been regarded as a hydrated arsenate of iron, was mentioned as far back as 1790 by Proust and also by other mineralogists about the same time. In 1801 Chenevix (*Phil. Trans.* 1801, 220) gave an analysis of an arsenate of iron, but it differs very much in composition from pharmacosiderite in that it contained 9 per cent. of copper. Probably it was not a pure specimen of this mineral. Vauquelin also published an analysis of an iron arsenate which was probably pharmacosiderite (Brongniart, *Traité de Min.*, 1807, II. 182), since he describes it as crystallising in cubes. He gave the following numbers:—

Fe_2O_3	...	= 48	per cent.
As_2O_5	...	= 18 to 20	,,
H_2O	...	= 32	,,
$CaCO_3$	...	= 2	,,

Neither of the above analyses referred to is satisfactory, as at that early date exact analytical methods of separating iron and arsenic acid were not known.

Berzelius (*Akad. Handl. Stockholm*, 1824, 354) published an analysis of pharmacosiderite, giving the following numbers:—

As_2O_5	...	= 37·82	per cent.
P_2O_5	...	= 2·53	,,
Fe_2O_3	...	= 39·20	,,
CuO	...	= ·65	,,
H_2O	...	= 18·61	,,
Residue	...	= 1·76	,,
		100·57	,,

This corresponds approximately to the formula $4Fe_2O_3.3As_2O_5.15H_2O$, for which the following are the percentages:—

Digitized by Google

As_2O_5	...	= 43·1
Fe_2O_3	...	= 40·0
H_2O	...	= 16·9

Since this analysis was not altogether satisfactory, and a simple formula cannot be readily deduced from the numbers, it seemed desirable to make a further analysis of the mineral.

The specimens taken for this purpose were from the mineral collection in the Oxford University Museum. They were certainly old Cornish specimens.

Green crystals were chosen as far as possible, as they seemed to be the purest and least altered, and the portion taken for analysis was carefully picked out under the microscope. An examination of some very fresh-looking brown crystals on one specimen showed that the brown colour was only due to surface alteration, since on crushing them they could be seen under the microscope to be nearly all green, with thin flakes of the brown material.

The specific gravity of the material analysed was found to be 2·798; the determination was made by means of a diffusion column of benzene and methylene iodide, by comparing the depths at which the mineral and beads of known specific gravity remained suspended.

The crystals analysed all showed the usual weak birefringence of pharmacosiderite, and a banded structure parallel to the cube faces was clearly visible between crossed nicols.

The following curious property of this mineral was observed.

On letting a good sized crystal stand for a few minutes in a solution of ammonia, the whole crystal became red, and afterwards, even when it was powdered as fine as possible, no green fragments could be seen remaining even in the middle of the crystal. The transparency of the crystal was not in the least degree affected by this treatment, neither were the optical characters altered. On allowing such a red crystal to stand in dilute hydrochloric acid for the same time, the green colour was restored to the whole crystal.

This experiment seems to show that the crystal is permeable to such liquids, though no pores are visible.

With regard to the water in pharmacosiderite, there is no doubt that some of it is only very loosely held. Experiments were made to ascertain the effect of different degrees of heat upon the crystals.

First the loss of weight of the mineral was determined, when finely powdered and subjected to a current of dry air; then the loss of weight

Digitized by Google

at 100° C.; and the loss of weight at about 180° C., at which temperature the crystals begin to turn brown.

Finally the total water was determined by igniting a weighed quantity of the mineral and weighing the water liberated.

The apparatus used was similar to that employed in the analysis of chalcophyllite (*Min. Mag.* 1899, XII. 121), a mixture of lead oxide and dioxide being used to retain the arsenic.

With regard to the rest of the analysis, the arsenic acid was estimated either by precipitation as sulphide and oxidation of the latter to arsenic acid by means of fuming nitric acid, and finally by precipitation as magnesium ammonium arsenate, or else by precipitation together with phosphoric acid directly, as the magnesium ammonium salt, in the presence of sufficient ammonium tartrate to prevent simultaneous precipitation of the iron. The iron and phosphoric acid were precipitated by ammonia when the arsenic had been removed as sulphide. They were then weighed together, and the phosphoric acid was afterwards separated from the iron by the molybdate method and thus estimated, its weight being then deducted from the combined weights of iron and phosphoric acid.

Since the colour of the crystals might suggest the presence of ferrous iron as a constituent of the mineral, some experiments were made in which a portion was dissolved in dilute sulphuric acid in an atmosphere of carbonic acid gas, and the solution tested with very dilute solution of potassium permanganate. Only two or three drops at most were decolourised by about half a gram of the mineral, so that only the merest traces of ferrous iron can be present.

Preliminary Analyses (I and II).

After making two analyses by these methods, a considerable deficit was noticed, and a more complete qualitative analysis revealed the presence of a small quantity of potash. This constituent was estimated in two separate portions as potassium platinic chloride. The first estimation was made on material from one of the specimens used in the previous analyses, but it is not certain to which it belongs, as it was picked from some fragments that had been kept from the previous analyses. The second determination of potash had to be made from another specimen altogether, of which there was not sufficient to make a complete analysis. The deficit was at first regarded as only due to experimental errors, and so most of the material at hand had been sacrificed for the other estimations; but the existence of potash was established in all the Cornish

Digitized by Google

specimens examined, and on p. 157 will be found a complete determination of all the constituents from a single specimen.

The analytical numbers are as follows:—

Estimation of Water.

·2749	gram	lost in dry air	·0044 gram	H_2O, corresponding to	1·60 %
·2749	,,	at 100° C.	·0268 ,,	,,	9·75 ,,
·3198	,,	in dry air	·0027 ,,	,,	·84 ,,
·3198	,,	at 100° C.	·0316 ,,	,,	9·88 ,,
·3990	,,	at 136° C.	·0571 ,,	,,	14·31 ,,
·2216	,,	at 130° C.	·0326 ,,	,,	14·71 ,,
·3990	gave on	ignition	·0784 ,,	,,	19·65 ,,
·2069	,, on	ignition	·0402 ,,	,,	19·42 ,,

The above determinations were made on different specimens.

The next two analyses (I and II) were made on portions of two specimens respectively.

Estimation of remaining constituents.

I.

·2715	gram	lost in dry air	·0022 gram	H_2O	corresponding to	·81 % H_2O
·2715	,,	at 150°	·0367	H_2O	,,	13·52 ,, H_2O
·2715	,,	on ignition	·0533	H_2O	,,	19·63 ,, H_2O
·3136	gave		·1582	$Mg_2As_2O_7$	,,	37·53 ,, As_2O_5
·3136	,,		·0100	$Mg_2P_2O_7$	,,	2·04 ,, P_2O_5
·3136	,,		·1232	Fe_2O_3	,,	39·29 ,, Fe_2O_3

II.

·3603	gram gave	·1398 gram	Fe_2O_3	corresponding to	38·81 % Fe_2O_3
·3603	,,	·0113	$Mg_2P_2O_7$	,,	2·06 ,, P_2O_5
·3027	,,	·1504	$Mg_2As_2O_7$	,,	36·85 ,, As_2O_5

Estimation of potash (a) on material used in the preceding analyses; (b) on new material.

(a)	·6082 gram gave	·1288 gram	$(KCl)_2.PtCl_4$	corresponding to	4·12 K_2O
(b)	·3136 ,,	·0434	$(KCl)_2.PtCl_4$	,,	2·68 K_2O

In Analysis II the proportion of water was not estimated, since it was abundantly clear from the preceding three determinations that the percentage of water is constant.

Digitized by Google

The following are the numbers obtained from the preceding analyses:—

	I.		II.		Mean result of water estimations.	
Total H_2O	19·63	...	[19·63]	...	Total water ...	19·63
As_2O_5	37·53	...	36·85	...	Water lost at about	
P_2O_5	2·04	...	2·06		130°	14·18
Fe_2O_3	39·29	...	38·81			
	98·49		97·35			
Deficit ...	1·51	...	2·65			
	100·00		100·00			

Since the deficit in these two analyses differs considerably, and since the percentages of potash determined directly in two different specimens are not at all in accordance, it is fair to assume that this constituent is very variable, and in fact two specimens from Königsberg, Hungary, were examined, and found to contain only a trace of potash.

If we consider the water contained in this mineral, it seems impossible to regard any of it as accidental, since while slight variations occur in the percentages under the varying conditions of the above experiments, the total amount seems to remain constant; and in the case where one sample lost more than another in a current of dry air, it lost less at 100° C., so that these results probably depend partly on the fineness of division of the powdered substance.

Nor does the exact percentage of water lost at 100° C. appear to have much significance, since the crystals hardly alter in appearance at this stage.

A real change, however, seems to begin to take place at 130°, as at this point the crystal liberates sufficient water to lose its transparency and green colour. It therefore seems that the percentage of water lost at about 130° should be taken into account in deducing a formula for this mineral.

Complete Analysis (III).

A subsequent and complete analysis of pharmacosiderite made on another Cornish specimen showed it to contain a slightly higher percentage of potash than any of the previously examined specimens.

The percentage of water was somewhat lower in this sample than in the others, which is remarkable, as it seemed to be constant in the three determinations. The numbers obtained were as follows:—

Digitized by Google

III.

·3398 gram	gave ·1702	$Mg_2As_2O_7$	=37·16 per cent.	As_2O_5
·3347	,, ·0631	H_2O	=18·85 ,,	H_2O
·3347	,, ·1258	Fe_2O_3	=37·58 ,,	Fe_2O_3
·3347	,, ·0063	$Mg_2P_2O_7$	= 1·20 ,,	P_2O_5
·3243	,, ·0761	$(KCl)_2PtCl_4$	= 4·54 ,,	K_2O
			99·33	

In proposing a formula for this mineral it is of course impossible to express in any molecular proportions the ratio between the potash and the iron, since the former is such a variable constituent. It is, however, possible to construct a formula which would express the constitution of the mineral if free from potash altogether, and to make a suggestion as to the part played by the potash.

The formula, which satisfies the ratios between the iron, arsenic acid and water, is $3Fe_2O_3.2As_2O_5.13H_2O$, or $2FeAsO_4.Fe(OH)_3.5H_2O$, in which the 5 molecules of water (15·53 per cent.) lost at about 130° are expressed as water of crystallisation. This gives the following percentages:

Total water	...	...	19·94	per cent.
Fe_2O_3	...	...	40·88	,,
As_2O_5	...	...	39·18	,,
			100·00	

The only way in which the potash can be brought into this formula is by supposing that some of the hydrogen in the hydroxyl groups is replaced by potassium. This would explain why, in the specimen, which contained most potash, all the other constituents showed a smaller percentage. If, on the other hand, the potash be considered to be present as potassium arsenate, forming a double salt with the iron arsenate, the percentage of arsenic acid ought to be higher in those specimens which contain most potash, but it is seen in fact that the ratio of iron, water and arsenic acids remains fairly constant in all cases.

An additional piece of evidence may be adduced in favour of the view that potash is an essential constituent of the Cornish pharmacosiderite, and not merely an impurity, though it may be present only in very small quantities.

While picking out material for the last analysis, it was found that the pharmacosiderite was closely associated with scorodite. Some of the latter was carefully picked out, but was found to be absolutely free from potash. Here then is a case of the two arsenates of iron side by side,

Digitized by Google

one containing potash in considerable quantity, and the other containing none. It may also be mentioned that one of the Königsberg specimens somewhat differed in crystalline form from the Cornish specimens, owing to the presence of tetrahedron faces; and this difference may possibly be related to the very small percentage of potash which it contained. The other Königsberg specimen, though it appeared to resemble the Cornish crystals in form, was considerably "weathered."

The final result of the above investigation is to propose the following formula as best representing the properties and constitution of pharmacosiderite:—

$$2FeAsO_4.Fe[O(H,K)]_3.5H_2O.$$

Note.—The presence of potassium was established by means of the microchemical test in all the specimens of pharmacosiderite examined. It is sufficient to immerse a fragment of the mineral in a drop of dilute hydrochloric acid and to add a drop of platinum chloride in order to obtain the characteristic octahedra of potassium platinic chloride.

Digitized by Google

On Langbeinite from the Punjab Salt Range.

By F. R. Mallet, F.G.S.,

Late Superintendent, Geological Survey of India.

[Read April 11th, 1899.]

In the eleventh volume of the *Mineralogical Magazine*, p. 317, in connection with the occurrence of blödite at the Mayo mines, in the Salt Range, allusion is incidentally made to a potassio-magnesian deposit, which was discovered there by Dr. H. Warth in 1878. It occurred as a lenticular stratum in the 'kallar' (impure rock salt) band separating the Sujewal and Purwálla salt beds. The material was more or less mixed up with the 'kallar' itself, and the deposit appeared to be of very limited extent.[1] I am informed by Dr. Warth that no further deposit of the kind has been discovered, so far as he knows; but this does not prove very much, for, since his retirement from the management of the mines, no search for potassium salts seems to have been made.

Specimens sent to the Geological Survey Laboratory, in Calcutta, were examined by Mr. A. Tween, whose analyses, given below, were published in the Catalogue to the Collection of Indian Geological Specimens sent to the Vienna Exhibition of 1878.[2]

	No. 1. Colourless salt.	No. 2. Pink-coloured salt.
KCl	3·80	61·43
NaCl	—	29·32
K_2SO_4	38·00	—
$MgSO_4$	58·02	7·78
H_2O	·62	2·10
	100·44	100·63

Specimens in the Vienna collection similar to No. 2 were examined by Professor Tschermak, who described them as "a white or reddish

[1] *Mem. Geol. Surv. India*, 1878, XIV. 80.

[2] Reprinted in Mr. A. B. Wynne's memoir on the geology of the Salt Range, *Mem. Geol. Surv. India*, 1878, XIV. 80.

Digitized by Google

granular mixture of sylvite, rock salt, and kieserite. The sylvite and rock salt can be at once recognised by the cleavage and flame reaction. The kieserite, which occurs in grains having a maximum diameter of 12 millimetres, is colourless, and shows the hardness and cleavage that I have given for the Hallstadt mineral.[1] In places, also, the kieserite is compact. An estimation of the water gave 12·99 per cent., which agrees with the theoretical amount, 13·04. From the kieserite changing, in a moist atmosphere, into epsomite, the pieces formed of that substance become quite disintegrated at the surface, and exhibit a constantly deciduous coating. In some pieces sylvite greatly predominates. Whether some kieserite also occurs in these, as might be conjectured in such association, has not yet been determined, for I have only been able to submit small pieces to examination."[2]

The colourless salt does not seem to have come under Professor Tschermak's observation. In Part IV. of *A Manual of the Geology of India*, published in 1887 (p. 142), I included it amongst the minerals of India, as a doubtful sulphate of magnesium and potassium, and remarked that, neglecting the KCl (doubtless intermixed sylvite) and H_2O, the percentages of $MgSO_4$ and K_2SO_4, amounting respectively to 60·43 and 39·57, when calculated to 100, although not corresponding accurately to any simple ratio between the bases, are fairly near 58·00 and 42·00, those required for the formula $(\frac{2}{3}Mg+\frac{1}{3}K_2)SO_4$, which is equivalent to $2MgSO_4.K_2SO_4$. I did not, however, consider that it would be justifiable to assume that the substance was a true double salt (and hence a simple mineral) without further examination, which circumstances did not allow of my making at that time.

Since then the existence of the compound just mentioned has been placed beyond doubt. In 1884 potassium salts were struck by a boring at the future mine of Wilhelmshall, north of Halberstadt, in Prussian Saxony. The result of Dr. S. Zuckschwerdt's examination of the fragments brought up led him, in 1891, to announce the discovery of "Langbeinite, a new potassium-magnesium sulphate," which his analyses, after he had freed the mineral from accompanying rock-salt, showed to agree very closely in composition with that required by the formula $K_2SO_4.2MgSO_4$.[3] Observations made by Director Steckert, after the

[1] *Sitzungsber. Wien. Akad.* LXIII. 1871, 305.

[2] *Tscherm. Min. Mitth.* 1873, 135; *Jahrb. d. k. k. geol. Reichsanst. Wien*, 1873, XXIII.; *Rec. Geol. Surv. India*, VII. 1874, 64.

[3] *Zeits. f. angewandte Chemie*, 1891, 356.

Digitized by Google

Wilhelmshall deposit had been opened out by mining, showed that the langbeinite always occurs in the older rock-salt beds, and is a mineral of primary formation, taking the place of polyhalite in those parts of the potassium-salt deposits where the quantity of calcium sulphate is insufficient for the formation of the latter mineral.[1] Comparatively recently langbeinite has been discovered in large quantity near Wolfenbüttel in Brunswick, where it occurs in the same way as at Wilhelmshall; and it has been found likewise in Westerregeln, and in Neu-Stassfurt, but under different circumstances, being in association with sylvite as well as rock salt, and partly of secondary formation.[2] Near Bernburg, again, the mineral occurs abundantly, overlying the carnallite stratum and beneath beds of rock-salt.[3] The first crystals of the mineral discovered were obtained at the last-mentioned locality, by Dr. Siebert, in 1897, and submitted to an elaborate optical and crystallographic examination by Otto Luedecke, who showed that the very complex crystals belong to the tetartohedral group of the isometric system.[4]

In the light of the above researches on the langbeinite of Germany, there seemed little room for doubting that the Punjab salt was of the same nature; but, in order that the question might be placed beyond the region of supposition, all the available material in the Museum was, at my request, lately sent to me for examination by the Director of the Indian Geological Survey, Mr. C. L. Griesbach, C.I.E.

Of the two specimens received, one (*Mineral Register, No. G 861*) is labelled as from the Mayo Mines, and presented by Dr. Warth, with the date of analysis added in Mr. Tween's handwriting, and is noted in the laboratory book as "colourless salt from the Salt Range." It is beyond question that to which Mr. Tween's analysis No. 1 refers. The other specimen will be referred to later on.

The colourless salt (*G 861*), of which there is about 4 ozs., is in irregular pieces, the largest about 3½ centimetres long; and, but for a few scattered inclusions of reddish salt (NaCl, coloured by Fe_2O_3), mostly not larger than a pin's head, though two or three are some millimetres in diameter, there is no macroscopic foreign matter. Only one piece (on which two adjacent faces are visible) shows any outward sign of crystallisation, and no cleavage is apparent. The fracture is uneven, or some-

---

[1] H. Precht, *Zeits. f. angewandte Chemie*, 1897, 68.

[2] H. Precht, *ibid.* 1897, 68.

[3] *Ibid.* 1897, 68; and O. Luedecke, *Zeits. Kryst. Min.* XXIX. (1898), 255.

[4] *Loc. cit.*

Digitized by Google

times conchoidal, and the hardness about 4. A determination of the specific gravity, by means of turpentine, in which the mineral is insoluble, gave 2·84 at 60° F., the pieces used being free from the NaCl mentioned above, and having surfaces composed of newly-made fractures. Portions of the mineral are whitish and translucent, owing to inclusions, but where it is free from such, or nearly so, it is colourless and transparent. In polarised light the mineral itself is isotropic. Luedecke, by the examination of slices (from near Bernburg) in sodium light between crossed nicols, was unable to detect any circular polarisation; but, as the material he employed was not fully transparent, he remarked that it was desirable that the experiment should be repeated on more perfect sections. I may add, therefore, that I obtained a similar negative result with the Punjab mineral, the plates used being perfectly transparent, and one of them about 4 millimetres thick.

The inclusions alluded to above, which, although nearly absent in some parts of the mineral, are abundant in others, range in size to over half a millimetre in length, though the great majority are much smaller. They are mostly of very irregular outline, but a few of them are lath-shaped, sometimes terminated by one or two pairs of parallel lines. In ordinary light the inclusions are as transparent and colourless as their host, and while the dark border to them is narrow, even where most pronounced, in some it is scarcely apparent. Hence they are not strongly differentiated from the enclosing mineral, and some are scarcely visible with the light mentioned, although very marked between crossed nicols. A good many of them contain bubble-like inclusions, with a dark border so broad that there is a comparatively small spot of light in the centre. These are presumably gas cavities. In no instance was any movement detected, or any indication of the presence of liquid.[1] Similar gas cavities, sometimes of larger size and more irregular outline, also occur in the langbeinite itself.

The transparent (solid) inclusions may be divided into a minority, which are isotropic, and the remainder, which are birefringent. Of the latter, those with irregular outlines either extinguish uniformly over the whole area, or else the area is divided into a few subordinate ones, often not more than two or three, in each of which uniform extinction takes [illegible] There are but few lath-shaped inclusions, the extinction in most [illegible]n being oblique, and in the remainder straight, suggesting monocrystallisation.

[illegible] reasons given below, water could scarcely exist, as such, in the inclusions.

Digitized by Google

The fragments of mineral selected for quantitative analysis were free from macroscopic impurity, and the surfaces were all freshly made fractures. Water dissolved the sample rather slowly, but completely, without a trace of residue. The result obtained was :—

		Calculated to 100.	Theory.[1]
K_2O	22·23	22·55	22·70
MgO	19·08	19·36	19·41
SO_3	57·27	58·09	57·89
NaCl	·41	—	—
H_2O	·84	—	—
	99·83	100·00	100·00

The sodium is evidently combined with the chlorine,[2] and the isotropic inclusions mentioned above should doubtless be referred to the resulting salt. The analysis just given shows that the birefringent inclusions must consist of potassium sulphate or magnesium sulphate, or both, in some form or other, and the close approximation of the analysis to the theoretical composition of langbeinite, suggests that the two sulphates are present in the inclusions in something like the same ratio as in the langbeinite itself. This condition would be satisfied if the inclusions consisted of kieserite or epsomite, and picromerite, in the proportion of one molecule of each, and such a mixture would be in accordance with the presence of water as shown by the analysis, and with the birefringence of the inclusions.

The langbeinite, when exposed, in powder, to the air, absorbs water rather quickly, an increase in weight of nearly 5 per cent. in 24 hours having been noticed. On the exposure being continued until the mineral ceases to gain in weight, the total increase is found to be rather less than 57 per cent., the precise amount depending on the temperature and humidity of the air at the time. Thus ten weighings of the same sample at different times gave results varying between 56·86 and 57·01 per cent.[3] As an absorption of 18 molecules of water equals 56·44 per

[1] K_2SO_4, 42·00 per cent.; $MgSO_4$, 58·00 per cent.

[2] The quantities found were Na ·15, Cl ·26, while theoretically the proportion is ·17 to ·26.

[3] Allowing for the water already present in the langbeinite (and the NaCl), this is equal to an absorption of about 58 to 58½ per cent., the excess over the theoretical amount being no doubt due to hygroscopic moisture. The latter cannot be extracted by H_2SO_4, as efflorescence takes place under such circumstances.

Digitized by Google

cent., it is clear that the decomposition of the langbeinite takes place in accordance with the following equation:—

Langbeinite. Water. Picromerite. Epsomite.

$$K_2SO_4.2MgSO_4 + 13H_2O = K_2SO_4.MgSO_4.6H_2O + MgSO_4.7H_2O.$$

The second specimen received from Calcutta (*Mineral Register, No. G 860*) is likewise from the Mayo Mines, and aggregates about half a pound, in pieces up to 5 or 6 centimetres long. The substance is grayish-white in some parts, pale reddish in others, and shows a rather coarse granular structure. I have, as yet, examined it qualitatively only, but it appears beyond doubt to be the material to which Mr. Tween's second analysis and Professor Tschermak's observations refer. It may, however, contain a larger proportion of kieserite than the portion examined by Mr. Tween, and I likewise picked some langbeinite out of it, the largest piece being about 2 centimetres long.

It is clear, therefore, that the saline deposit in question was composed of at least four minerals, their relative proportions varying considerably, perhaps greatly, in different parts of the stratum.[1]

The langbeinite melts at a red heat, and, on cooling, solidifies to a white, more or less distinctly crystallised, mass. This observation naturally suggested an easy method for its artificial production, and the inference was confirmed by experiment. When powdered K_2SO_4 and $MgSO_4.7H_2O$ are mixed (more conveniently after dehydration of the latter) in the molecular proportion of 1 to 2, and ignited, the mixture fuses at a full red heat to a clear transparent liquid. During cooling and solidification there is a considerable amount of crepitation. The resulting white mass generally has one or more drusy cavities in the interior, the crystals on the walls of which are (geometrically) octahedra, with faces some of which are smooth and others somewhat cavernous. A few crystals show faces of the rhombic dodecahedron, replacing octahedral edges. The crystals tend to arrange themselves with similar orientation, and sometimes form columns composed of octahedra with their respective axes parallel. The artificial mineral is isotropic, like the natural one. During fusion SO_3 is slowly given off, and eventually the melt becomes pasty from admixed magnesia, while it no longer dissolves completely in water.

---

[1] Since the above was written Dr. Warth has informed me that the salts in question were found at two spots, about 300 feet apart. At one of these magnesium salts predominate; at the other, potassium salts; the latter may perhaps have been a little higher up (on a higher horizon) in the Kallar bed than the other, but this is uncertain.

Digitized by Google

In 1880 Dr. H. Precht described the artificial production of a salt to which he assigned the formula $K_2SO_4.2MgSO_4.H_2O$, but which, after the publication of Dr. Zuckschwerdt's results in 1891, he regarded as $K_2SO_4.2MgSO_4$. It is precipitated at a boiling heat, preferably at a steam pressure of 2 or even 4 atmospheres, from a concentrated solution of magnesium chloride, with potassium sulphate and excess of magnesium sulphate.[1] This latter method will, perhaps, be regarded as not without interest in connection with the views expressed by Messrs. Middlemiss and Holland as to the origin of the salt marl and gypsum of the Salt Range.[2]

In conclusion, I may add that the known minerals associated with the rock salt of the Salt Range include the following[3]: –

1st. Of Primary Formation.

Rock-salt (stratified; in beds of immense thickness and extent). A. B. Wynne, *Mem. Geol. Surv. India*, 1878, XIV. 76, 213, 231, 284.

Sylvite[4] (stratified; the mineral has been found in one or two spots only, mixed with rock-salt, kieserite, and langbeinite). G. Tschermak, *Min. Mitth.* 1873, 135, and *Rec. Geol. Surv. India*, 1874, VII. 64.

Anhydrite (stratified; more or less mixed with gypsum; *cf.* secondary gypsum). A. B. Wynne, *loc. cit.* 74; T. H. Holland, *Rec. Geol. Surv. India*, XXIV. 1891, 285.

Gypsum? (stratified; in extensive beds, as a rule overlying the rock-salt; *cf.* secondary gypsum). A. B. Wynne, *loc. cit.* 78, 300.

Kieserite (stratified; *cf.* sylvite). G. Tschermak, *loc. cit.*; F. R. Mallet, *Min. Mag.* XI. 1897, 317.

Langbeinite (stratified; *cf.* sylvite). F. R. Mallet, *Min. Mag.* Vol. XII, 1899, 159.

Dolomite (stratified). A. B. Wynne, *loc. cit.* 74, 134, 231, 267; C. S. Middlemiss, *Rec. Geol. Surv. India*, XXIV, 1891, 26; H. Warth, *ibid.* XXIV. 69.

---

[1] *Chemische Industrie*, III. (1880), 418, and *Zeits. f. angewandte Chemie*, 1897, 68.

[2] *Records, Geol. Surv. India*, XXIV. 26 and 235.

[3] The references are far from complete, only some of the more important being given. For the literature of the subject, *Mem. Geol. Surv. India*, Vol. XIV.; *A Manual of the Geology of India*, Parts II. III. and IV., and *Rec. Geol. Surv. India*, XXIV, 19 and 230, may be consulted.

[4] The primary nature of the sylvite and kieserite, and secondary character of the selenite, glauberite, and blödite, was pointed out by Dr. Warth in a letter respecting blödite that I received from him in 1897.

Digitized by Google

Quartz (as crystals in the anhydrite and gypsum). H. Warth, *Inland Customs Administration Report*, 1870-71; A. B. Wynne, *loc. cit.* 268; T. H. Holland, *Rec. Geol. Surv. India*, XXIV, 1891, 231.

2ND. OF SECONDARY FORMATION.

Halite (crystals in fissures of the rock salt, and fibrous). H. Warth, *Inland Customs Admin. Report*, 1869-70, Appendix H; *Manual Geol. Ind.*, IV. 34.

Gypsum (altered anhydrite). A. B. Wynne, *loc. cit.* 74; T. H. Holland (who holds that much of, possibly all, the gypsum of the Salt Range is altered anhydrite), *Rec. Geol. Surv. India*, XXIV. 1891, 235 (altered dolomite?); C. S. Middlemiss, *ibid.* 26.

Selenite (crystals in fissures of the rock salt). H. Warth, *Mem. Geol. Surv. India*, XIV. 1878, 80; *Min. Mag.* XI. 1897, 311.

Glauberite (crystals in fissures of the rock salt). H. Warth, *cf.* selenite; W. Schimper, *Zeits. f. Kryst.* I. 1877, 70.

Blödite (crystals in fissures of the rock salt). H. Warth, *Min. Mag.* XI. 1897, 311; W. Schimper, *loc. cit.*; F. R. Mallet, *Min. Mag.* XI. 1897, 311.

Picromerite? (probably exists in small quantity, owing to the hydration of langbeinite). *Cf.* p. 168.

Epsomite (as an efflorescence, due, in part at least, to hydration of kieserite). H. Warth, *Inland Customs Admin. Report*, 1869-70, Appendix H; G. Tschermak, *loc. cit.*; A. B. Wynne, *loc. cit.* 79 (probably also in small quantity, owing to hydration of langbeinite). *Cf.* p. 163.

Digitized by Google

On a mass of Meteoric Iron from the neighbourhood of Caperr, Rio Senguerr, Patagonia.

By L. Fletcher, M.A., F.R.S.,
Keeper of Minerals in the British Museum.

[Read April 11th, 1899.]

In the month of September, 1869, Captain Musters, who was at that time making an expedition through Patagonia, had his attention called to a heavy mass of material which he took to be marble. In the account of his journey he afterwards wrote (from memory) as follows[1]:—

"There is in this place, which is called by the Indians Amakaken, a large spherical boulder of marble, which it is the custom of the Indians to try their strength by lifting. Casimiro informed me that this stone had been there for many years, and the custom was very old. It was so large and heavy that I was just able to grasp it with both arms and raise it to the level of my knees, but some of the Indians managed to lift it to their shoulders."

Amakaken is indicated on Musters' map as situated in longitude 71°56′ West of Greenwich, and latitude 48°10′ South. The above-mentioned Casimiro, who accompanied Captain Musters throughout the expedition, had been recognised by the Argentine Government in 1865 as head chief of the Tehuelches,[2] the natives inhabiting the interior of Patagonia. The Tehuelches are by country, race, language and character altogether distinct from the Pampas Indians.[3]

Many years later, on the 4th of April, 1896, the mass was seen by the Director of the State Museum of La Plata, Dr. Francisco P. Moreno, then making a voyage of exploration in the interior of Patagonia. Dr. Moreno perceived that the material was not marble but iron, and recognising that it must be of meteoric origin, secured the mass (weighing 114

[1] *At Home with the Patagonians.* By George Chaworth Musters. London, 1871, p. 87.

[2] *Ibid.* p. 46.

[3] *Ibid.* pp. xix, xx.

Digitized by Google

kilograms, or 251 lbs.) for the La Plata Museum. In January last Dr. Moreno came to London to be at hand to give geographical information on behalf of the Argentine Government to the Commission appointed to settle by arbitration the boundary of Argentina and Chili; and he took the opportunity of bringing with him, in addition to other specimens of scientific interest, a model of the meteorite and a small fragment weighing 78 grams (2¾ oz.) which had been broken by him from a corner of the original mass. These he presented to the British Museum for examination and preservation.

Dr. Moreno reports that the name Amakaken (*i.e.* Emelk'aiken) was given by Captain Musters through a slip of memory, and that the place was really farther north on the plateau south of Rio Senguerr, Chubut Territory, situated about longitude 70°20′ West and latitude 45°15′ South; the nearest place with a name being a tribal encampment called in the Gennaken language Caperr.

According to measurements taken from the model, the mass is 48 cm. (19 in.) long, 31 cm. (12¼ in.) broad, and 27 cm. (10½ in.) high. The shape is irregular, but one side, parallel to the length, is sufficiently flat to afford a convenient base. The surface, like that of most meteoric irons, presents both large and small concavities. One of the former is 10 cm. across; one of the latter, nearly a hemisphere, is 8 cm. across.

That the structure of the material belongs to the kind termed octahedral is very manifest from mere inspection of the surface of fracture of the fragment, for the simple action of air and moisture has already sufficed to differentiate the constituent alloys and reveal their arrangement.

Relative to a solution of copper sulphate, the iron is "active," the reduced copper being visible within one or two minutes from the beginning of contact.

The iron is soft, and is thus easily cut with a hack-saw. No troilite or silicates were to be seen on any of the small faces which were prepared and polished.

A polished face (40 mm. long and 17 mm. wide), the largest which could be got from the fragment, was etched with bromine-water and gave distinct Widmanstätten figures. In this section the beams of dull grey kamacite have an average width of 1 mm. Occasionally there are three or four of them in immediate succession without any evident intervening plessite, their edges being only roughly rectilinear and parallel. As usual, each beam of kamacite is bordered by a thin bright line of tænite, which soon after the etching acquires a yellow tint. The plessite is comparatively plentiful, and occupies a considerable part of the etched

Digitized by Google

surface, one area being 5 mm. long and 5 mm. wide, and a second 3 mm. long and 2½ mm. wide. The ridges or "combs," described by Reichenbach, are very conspicuous, and appear to result from thin and numerous plates of tænite traversing the plessite.

Embedded directly in the kamacite, and not separated therefrom by lines of tænite, are some thicker lustrous steel-gray homogeneous-looking enclosures which were found to be schreibersite. As the latter mineral (phosphide of iron and nickel) is very similar in aspect to cohenite (carbide of iron and nickel) and may easily be mistaken for it, a small piece of iron containing one of these enclosures was cut out and filed down until the greater part of the enclosing iron had been removed. Owing to the probable brittleness of the small enclosure, the mechanical reduction was not carried further, but the fragment was now immersed in cold dilute hydrochloric acid (1 in 20). The enclosure immediately became silver-white, and remained so while in the acid, but the enclosing iron at once became dull black, and continued so during the solution. After two days the enclosure dropped out of the fragment, and could be separately examined. It proved to be a phosphide, and therefore schreibersite. It was unaffected by a solution of copper ammonium chloride.

The etched surface is also speckled with other very minute enclosures which have the same lustre and colour as the larger ones (schreibersite). The small specks and the short thin lines of this material appear here and there to take the place of tænite, while in other parts they lie between tænite and adjacent kamacite.

Small fragments of the iron were allowed to stand for some weeks in cold dilute hydrochloric acid (1 in 20), which was occasionally renewed. The greater part (kamacite) became dull black, and slowly passed into solution. The residue consisted of (1) lustrous thin plates, containing no phosphorus, and quickly attacked by copper ammonium chloride solution (tænite); (2) some dull black material dissolving immediately in *aqua regia* and containing no chromium, copper, sulphur or phosphorus: it is presumably an iron-nickel alloy, possibly another form of the tænite; and (3) schreibersite. There was no graphitic carbon, silica or silicate. The tænite and schreibersite were not sufficient in quantity to allow of their quantitative analysis.

Relative to water at 4° C., and allowing for displaced air, the specific gravity at 18¼° C. of two thin slices, together weighing 4·8424 grams, was determined to be 7·837 (uncorrected 7·86).

These two thin slices were dissolved in *aqua regia*, and left an unweighable residue consisting of a few black particles of almost microscopic

Digitized by Google

size in which no chromium could be detected by the blowpipe. After removal of the nitric acid by evaporation to dryness with hydrochloric acid (when no silica was obtained), the material was brought again into solution and divided into five equal portions, which were analysed according to the methods mentioned in a previous paper,[1] except that the iron was precipitated four times instead of twice by sodium acetate before its final precipitation by ammonia. The phosphorus was determined twice, once from a special portion of the solution by the method previously mentioned, and a second time by separation from the ignited iron precipitate by the ammonium sulphide and molybdic methods: the numerical results were virtually identical. The nickel and cobalt were precipitated twice as higher oxides by sodium hydrate and bromine-water, and weighed together in the metallic state. The cobalt was then separated by the nitrite method, and weighed as potassium cobalt sulphate.

The following numbers were obtained for the percentage composition:—

	Caperr, Patagonia.	The Joel iron, Atacama.
Iron	89·87	90·45
Nickel	9·33	8·80
Cobalt	0·53	0·54
Phosphorus ...	0·24	0·26
Chromium ...	trace	—
Copper	trace	trace
Sulphur	nil	nil
	99·97	100·05

For the purpose of comparison, the percentage chemical composition of one of the Atacama meteoric irons,[2] to which there is a considerable resemblance of structure, is given in the last column.

This is the first meteorite found in Patagonia, and its latitude is the most southern yet recorded for any meteoric iron. The next in point of southern latitude was the large Australian mass (now in the British Museum), which was found in latitude 38°11′ S., at Cranbourne, near Melbourne.

[1] *Mineralogical Magazine*, 1887, Vol. VII, p. 124.

[2] *Ibid.* 1889, Vol. VIII, p. 263.

Digitized by Google

On the Cliftonite and Tænite of the Meteoric Iron found in 1884 in the Sub-district of Youndegin, Western Australia.

By L. Fletcher, M.A., F.R.S.,
Keeper of Minerals in the British Museum.

[Read June 20th, 1899.]

In a previous paper, published in 1887,[1] the author described some remarkable crystals of graphitic carbon (Cliftonite) obtained from the meteoric iron of Youndegin, Western Australia; the isolated material weighed only 3 milligrams, and had been left as an insoluble residue after the treatment of 8·32 grams of the iron with *aqua regia*.

1. *Limited distribution of the Cliftonite in the mass.*

In the following year (1888), with a view to isolating more of the graphitic crystals and at the same time other mineral constituents of the mass, a large piece of the same meteoric iron, filed free from rust and weighing 97·25 grams, was submitted to the action of slightly heated dilute hydrochloric acid (1 of S.G. 1·12 with 10 of water), the acid being renewed from time to time as exhaustion took place. The action was allowed to proceed night and day until, after the lapse of a fortnight, evolution of hydrogen was no longer manifest. During this time the undissolved residue was kept as free from disturbance as possible, for the graphitic crystals were known to be brittle and easily reducible to powder. During the action of the acid the first appearance of Cliftonite was carefully watched for, in order that the mode of occurrence of the crystals in the mass might be ascertained; but not a single crystal was seen in the course of the whole operation, and the undissolved residue itself, when afterwards examined, was found to be almost wholly attracted by the magnet, and the unattracted part to be completely dissolved by *aqua regia*. As already recorded,[2] two other fragments, weighing 7 grams and 2 grams respectively, had yielded no graphitic material on solution.

[1] *Mineralogical Magazine*, 1887, Vol. VII, p. 121.

[2] *Ibid.* p. 125.

Digitized by Google

The Cliftonite is therefore localised in one or more parts of the mass, and not uniformly distributed through it. The more common variety of graphitic carbon is also similarly local in its occurrence in meteoric iron, being present in various masses as large nodules.

2. *Tænite.*

During the solution small thin lustrous black plates, only slightly if at all attacked by the dilute acid, were seen to be distributed throughout the more soluble material, many of the plates being parallel to each other. Their appearance was so like that of graphite that it was at first expected they would prove to belong to that species; but on examination of the plates initially set free, they were found to consist of a material strongly attracted by the magnet, flexible, completely soluble in strong hydrochloric acid and also in nitric acid of S.G. 1·2; they had an immediate reductive action on a cold solution of mercuric chloride, and in a day or two passed completely into solution. They contained no phosphorus. After standing for two days in water, a plate became oxidised on the surface and lost its brightness.

From these characters it was inferred that, notwithstanding their black colour, the plates consisted of an alloy of nickel and iron belonging to the tænite group.

The thin plates, as set free, were pushed with a thick platinum wire into a separate dish, and were kept isolated from the rest of the undissolved material as being a comparatively definite and homogeneous constituent of the meteorite. When all the plates obtainable had been collected, they were again treated with dilute hydrochloric acid for some days. Further, a small quantity of adherent schreibersite was carefully broken off and removed; it was found through the sense of touch by means of the greater resistance felt when the particles of schreibersite on the flexible plates were pressed with the thick platinum wire: owing to their flexibility the plates themselves are somewhat yielding, and thus give a suggestion of softness when they are pressed with the wire. The plates were washed with water, afterwards with alcohol, and then dried and weighed (0·0870 gram). Later there were added some further plates which had been similarly obtained from small waste fragments of the iron produced during the cutting of the mass; their weight was not determined, but it must have been comparatively small.

In the course of the present year (1899) it was resolved to make a quantitative analysis of the alloy, notwithstanding the smallness of the amount available for the purpose. During the eleven years which had

Digitized by Google

passed since its isolation, the alloy had been lying in a weighing tube inside a closed box. It still retained its lustre, and appeared to have undergone no alteration.

(*a*). The weight, however, was now 0·1026 gram, and the excess (0·0156 gram) over the amount (0·0870 gram) isolated from the large piece was greater than was likely to be due to the plates which were obtained from the small waste bits of the iron, and had been added after the weight of the main material (0·0870 gram) had been determined.

(*b*). The material, though entirely attracted by the compass-needle, did not appear to be as strongly attracted as nickel-iron.

(*c*). Cold solution of mercuric chloride had no perceptible action on the plates even in the course of some days. In this respect the plates behaved quite differently from before; for in 1888, as already stated, the reductive action had been immediate. After a fortnight, although a flake was still apparently unacted upon by the mercuric solution, there was really only a thin crust of undissolved material left; for when touched with a wire the flake completely collapsed. On the other hand, a boiling solution had an immediate solvent action, only a trivial amount of black material being left. This black material was immediately dissolved by strong hydrochloric acid, and was therefore not carbon.

As a cold solution of mercuric chloride has no solvent action on the magnetic oxide of iron, the later behaviour of the plates is such as would result if they had been superficially changed into the black magnetic oxide.

(*d*). The specific gravity of the material, as determined from 0·0669 gram with the use of a 3-cub. cent. pyknometer, was 6·75. This number is so much below those corresponding to iron and nickel that, with every allowance for the difficulty of accurately determining the loss of weight in water for so small an amount of dense metal, it suggests an oxidation of the material. It may be mentioned that during the determination great difficulty was experienced in removing all the interpenetrant air; the plates were composite, and the air was only slowly removed from the intervening spaces by an oft-repeated use of the air-pump.

(*e*). The above-mentioned material, weighing 0·0669 gram, was treated with *aqua regia*, and in a short time was almost wholly dissolved. Long digestion, however, did not produce complete solution; a minute amount of insoluble reddish-purple pulverulent matter was still visible. It was collected and weighed by the double-filter method after being dried at 165° C. The colour had now changed from reddish-purple to black. The material weighed only 0·0006 gram. As it completely disappeared

Digitized by Google

on ignition, it was probably an organic compound, and was possibly due to the action of the *aqua regia* on a trace of Cohenite, a carbide of iron and nickel occasionally present in meteorites.

The solution was analysed according to the methods already described,[1] except that the number of precipitations with sodium acetate was six instead of four.

The resulting numbers were—

Iron	0·0885	gram.
Nickel (Cobalt) ...	0·0236	,,
Phosphorus ...	0·0004	,,
Total	0·0625	,,

Copper was found to be present, but its weight was not determined; though the amount was small, the proportion of the copper was probably larger than for an average piece of the meteoric iron itself. Only a trace of magnesium was found.

There was thus 0·0044 gram still unaccounted for. The deficit was presumably due to combined oxygen, for the analysis had been made with great care, and had proceeded without evident mishap. The still remaining material, weighing 0·0285 gram, was then heated in a porcelain boat in a current of hydrogen, and was found to experience a loss of 0·0018 gram. In the same proportion, 0·0669 gram of the material should lose 0·0042 gram, and the result is thus confirmatory of the above explanation of the deficit.

After the heating in hydrogen, the material was no longer black, but bright tin-white in colour.

If the small amount of phosphorus be deducted, as being in combination with iron and nickel as schreibersite having the formula Fe_2NiP, the percentage composition of the Youndegin tænite is—

Iron	61·87
Nickel (Cobalt)	38·13
	100·00

The alloy is therefore almost identical in chemical composition with that isolated by Cohen and Weinschenk from the Glorieta meteorite, the percentage composition of which was determined to be:—

Iron	63·04
Nickel (Cobalt)	36·96
	100·00

[1] This volume, p. 170.

Digitized by Google

A Three-Circle Goniometer.

By G. F. Herbert Smith, B.A.,

Assistant in the Mineral Department of the British Museum.

[Read April 11th, 1899.]

THE object of goniometrical measurement is to determine in the simplest and quickest manner possible the geometrical constants of crystals and the indices of their faces. The ideal instrument should enable the observations to be conveniently and quickly made, and present them in such a form that the indices of the faces may be easily calculated. It is claimed for the form of goniometer described in this paper that it does approximate to such an instrument. Before entering into the description it will not be out of place to discuss briefly the two types at present in existence, and point out their advantages and disadvantages.

I. *The One-Circle Goniometer.*

This instrument, which owes its conception to Wollaston, first made possible the accurate measurement of the angles between the faces of a crystal. In the original form the graduated circle was vertical, but Babinet afterwards introduced a goniometer with a horizontal circle. Improvements in details—such as the employment of telescope and collimator, mechanical means for adjusting the crystal, convenient object-slits, &c.—followed in due course, until finally we have the perfected instrument of the present day.

The grave objection to this form of goniometer is the necessity for readjusting the crystal for each zone, and consequently for identifying at least two faces in this zone. This identification is frequently by no means easy even in the case of fair-sized crystals, and becomes exceedingly difficult when the crystal is small and rich in faces; yet the smaller the crystal the better has been its chance of undisturbed growth.

Faces often occur which do not lie exactly in the zone under measurement, but there is no way of accurately determining the deviation from the zone. Further, if several images occur close together, but not in the same zone, it will very probably be impossible to determine the precise position of each.

Digitized by Google

Since in this method measurements are, as far as possible, always made in zones, the indices of the faces may be readily calculated by means of the law of zonality.

II. *The Two-Circle or Theodolite Goniometer.*

Since we are concerned with the relative and not the absolute position of crystalline faces, we may refer the position of any face to that of a pole on a sphere, and denote it by means of two co-ordinates—the polar distance and azimuth, corresponding to the N.P.D. and R.A. of a star in astronomy. The theodolite goniometer gives at once such co ordinates for any face.

An instrument of this character was employed many years ago (in 1874) by Miller to determine the faces presented by a platinum bead which had been strongly heated before the blowpipe. He merely fixed a goniometer with a vertical circle on another with a horizontal circle. His method and results were published after his death by Prof. W. J. Lewis,[1] but do not seem to have attracted much attention. Rather more than a decade later Prof. V. Goldschmidt[2] described a goniometer with two circles, which is practically the same as Miller's. Almost at the same time Herr Czapski[3] gave a description of his form of goniometer, in which the crystal has motion about a vertical axis, while the telescope and collimator, inclined to one another at a small angle, move about a horizontal axis. Shortly afterwards Prof. Fedorow[4] pointed out that he had in 1889 published in the proceedings[5] of the St. Petersburg Mineralogical Society a description of a two-circle goniometer. This again is, except for the use of an auto-collimating telescope, of the same type as Miller's.

In employing a goniometer of this kind we adjust the face or one of the faces of greatest symmetry accurately parallel to the circle carrying the crystal. For any other face the reading of this circle gives the azimuth, and of the second circle the polar distance, after the subtraction of constants in the two cases, if necessary.

It is evident that the chief difficulty involved in the older method is in

---

[1] *Proc. Camb. Phil. Soc.*, 1882, IV, 236. Abstract in *Zeits. Kryst. Min.* 1883, VII, 619.

[2] *Zeits. Kryst. Min.* 1893, XXI, 210.

[3] *Zeits. für Instrumentenk.*, 1893, 1.

[4] *Zeits. Kryst. Min.* 1893, XXI, 574.

[5] XXVI, 458. Abstract in French in *Bibliothèque géologique de la Russie*, 1890, VI, 97

Digitized by Google

this type of instrument entirely overcome. No readjustment of the crystal is required. Each face is observed once only, and the position corresponding to every image is accurately defined.

Did we denote a face by means of these co-ordinates, no exception could be taken to this method. We, however, have to deduce from them the indices of the faces, and this is in general a tedious and troublesome process. Unless a zone includes the face of reference, or its edge is perpendicular to that face, no immediate use can be made of the law of rational indices on which depends the anharmonic ratio of four poles in a zone, and, consequently, Miller's simple logarithmic formulæ cannot be employed. The formulæ devised by Profs. Goldschmidt and Fedorow[1] are cumbersome, and not readily adapted to logarithmic computation.[2]

Further it is impossible to determine without a troublesome calculation whether three faces lie in a zone, unless the zone be one of those mentioned above. Indeed, much of the time saved in the observations is lost in the calculations.

It may be remarked that, if an unknown crystal be measured of which the symmetry is not obvious, the pole of a face of symmetry may not have been chosen as pole of reference, in which case it is exceedingly difficult to identify the crystal.

III. *The Three-Circle Goniometer.*

The advantages of both methods may readily be combined by the addition of a third circle. The crystal is adjusted once for all, and measurements may be made in any desired zone, the orientation of which is at the same time determined.

For crystals small enough to be firmly held by the wax in all positions by far the most convenient arrangement is to give all three motions to

---

[1] *Loc. cit.*

[2] *Cf.* the very suggestive remarks by Signor C. Viola, *Zeits. Kryst. Min.*, 1898, XXX, 423:—

"Ich bin der Meinung, dass, sowohl was die Messung der Krystalle, als auch was die Signatur der Flächen anbetrifft, man hauptsächlich auf die Zonen Rücksicht haben muss, denn nur dadurch kann eine Erleichterung herbeigeführt werden, obwohl die meisten Flächen von den Zonen ein wenig abweichen.

"Das Princip der Zonen, oder was gleich ist, das Princip der Rationalität darf nicht bei Seite gelassen werden, wiewohl es in der Natur nicht mit absoluter Strenge zutrifft. Ein solches Princip ist eben der Leitfaden der Krystalle, wie das Newton'sche Gesetz, das auch nicht genau in der Natur gilt, für die Bahnberechnung der Planeten jedoch das Fundament bildet.

"Erfüllt ein Theodolithgoniometer solche Bedingungen nicht, so hat es besseren Instrumenten Platz zu machen."

Digitized by Google

the crystal, but, if necessary, the telescope and collimator might have one or more.

(*a*) *The Instrument.*

This form of goniometer consists essentially of three circles :—

(A)[1] The horizontal circle,
(B) The vertical circle,
(C) The third circle.

These must be so arranged that the axes of A and C are always at right angles to B, though inclinable at any angle to each other. At the same time the axis of A must be perpendicular to the bisectrix of the angle between the telescope and collimator, and all three axes must, at any rate approximately, intersect in the optic centre.[2]

The last condition must be fulfilled to avoid the necessity for re-centering any but very small crystals during the course of observations. If a collimator be used, re-centering is not essential to the accuracy of the measurements.

The axis of B is adjusted in the same way as for a theodolite goniometer.[3] A face is adjusted parallel to this circle, so that no movement of the reflected image takes place on rotation, and the axis adjusted until this image coincides with the cross-wires. B is now turned about the axis of A through a right angle, and the axis of C is adjusted at right angles to that of B in the same way as the latter axis has been adjusted to that of A.

As an experiment a Fuess Model II goniometer has been converted into this form by the substitution of a two-circle arrangement in place of the original crystal-holder. Plate II, which is reproduced from a photograph of the actual instrument, shows the general construction. Since it is of the utmost importance that all the parts should be absolutely rigid, some more efficient connection between the extra circles and A (retaining the nomenclature used above) is required than that already provided. The horizontal plate of the additional apparatus is rigidly attached by means of three clamps to the rabbet underneath it, which, in its turn, is firmly screwed to A. Underneath this plate is a short cylindrical piece, which fits into the hole already in A and serves to keep

[1] Throughout this paper reference will be made to the circles by these letters.
[2] The intersection of the axes of the telescope and collimator.
[3] *Vide* Fedorow, *loc. cit.*

Digitized by Google

the additional apparatus in position when rotating independently of this circle. In this way the reading for a face parallel to B may be made a convenient quantity, such as 0°0′. On the top of the plate is fixed the counterweight, and opposite this the vertical piece carrying the cone of B. This piece has from a side aspect an L-shaped termination, and is attached to the horizontal plate from underneath by four screws. Mechanical means for raising or lowering the axis of B have been omitted, as their provision would have weakened this important junction. This axis may, however, be raised a small amount by packing with paper, which is easily cut to shape and practically incompressible. By slotting the lower holes, through which the screws pass, B may be moved to or from the axis of A; an adjustment required if the axis of C does not, when adjusted in direction, pass through the optic centre. The axis of B has three adjustment screws: two (visible in the figure) to bring it into the horizontal plane, and one (at the back) to make it intersect the axis of A. In the present case it was found to be appreciably too low, and was raised, in the manner described, about 1 mm. The axis of C has also three adjustment screws: two to bring it into a plane parallel to B and one to make it intersect the axis of this circle.[1] It can, if necessary, be made to pass through the optic centre in the manner described above. Both circles have clamps and slow motions and fixed verniers reading to minutes. The circle C for the sake of lightness has been constructed of aluminium; the remainder of the apparatus of bronze. In setting off the graduations on B it was arranged that, where the axis of C is vertical, the reading should be as nearly as possible 0°0′. This condition has not quite been fulfilled. The axes of B and C more nearly intersect when the reading is 0°80′. The extra apparatus is clamped to A in such a position that the reading of this circle for a face parallel to B is exactly 0°0′. The crystal-holder is of the ordinary type, and has the usual adjustments. The counterweight to C and the crystal holder is attached on the other side of B, to prevent any shearing stress on the cones of the latter. Springs are added to keep B and C in position. The circles B and C are about 11 and 9 cm. in diameter respectively. This permits of the former being turned about the axis of A through 190° approximately,[2]

[1] The latter adjustment may be employed to make the reading of B a convenient quantity when the axis of C is vertical.

[2] That this angle could not be conveniently made larger is one of the disadvantages of adapting an existing goniometer. It might, however, in an instrument entirely new from the beginning be easily arranged that B could be turned round the axis of A through nearly 300°.

Digitized by Google

when the telescope and collimator are inclined to one another at an angle of 70°, and of the latter through 240° approximately, when the axis of B bisects the interior angle between the telescope and collimator. The tubes of the telescope and collimator are covered with india-rubber, to prevent jarring in the event of either B or C coming into violent contact with them.

(*b*) *How to use the instrument.*

If we adjust the edge of a zone parallel to the axis of C, and rotate the crystal about this axis, we bring in turn all the faces in this zone parallel to B. Rotating A[1] until it reads 0°0′, in which case the image reflected from a face parallel to B is on the cross-wires, and for convenience making the axis of C vertical (though this is not essential), we note the readings when the different faces are parallel to B. If we then proceed to clamp C when some face is in this position and rotate B, we bring any zone containing the face parallel to A, and find the readings of the latter circle for all faces lying in the zone. In other words, we can take two-circle measurements with the pole of any face in a particular zone as pole of reference.

It is, therefore, easy to see that for any zone adjusted by means of B and C parallel to A,

A gives the angles in the zone,

B the angle between this zone and the zone of reference,[2] and

C the pole, whether representing an existing face or not, in which the zones intersect.

Since A can be rotated through 190° at the most, only half a zone can be measured at a time. To complete the zone we must rotate C through 180°, and B back through the zero position till the axis of C makes the same angle with the vertical as before, but on the other side.

In setting up any crystal for measurement we should choose the zone of greatest symmetry as zone of reference; [111] and [010] in the case of hexagonal and monoclinic crystals respectively. In this way, except on triclinic crystals, there will be a possible face parallel to C. By keeping this circle vertical we may take measurements with the pole of the face parallel to it as pole of reference, and thus get a general idea of

---

If the axis of C be vertical, this zone may be measured whatever be the reading of A, but it is only when the latter reads 0°0′ that the reading of C for any particular face indicates the position in which it is parallel to B.

[2] The zone whose edge is parallel to the axis of C.

Digitized by Google

the positions of the faces on the crystal. We can see at once from a stereographic projection in which zones it would be best to take measurements.

Although convenient, it is by no means essential that the zone of reference should be one of symmetry. If an unknown crystal, whose symmetry is not obvious, be measured for identification, the most prominent zone would naturally be chosen for reference, and measurements made to determine the positions of the remaining faces with respect to it.

The extra apparatus has been constructed by Messrs. Troughton and Simms, the well-known opticians and mathematical instrument makers, of London. The author is glad to have this opportunity of putting on record his gratitude to them for the able and careful manner in which they have carried out his ideas.

The following measurements of a crystal of anorthite from Monte Somma have been made with the three-circle goniometer here described, and are added as an example of the readings obtained when a crystal is measured according to this method:—

Observed Readings.

Zone of Reference [100]			A	B	C	C (from *c*)	Dana.
	1	*c*(001)	0° 0′	0°30′	198°32′		
	2	*n*(02$\bar{1}$)	,,	,,	151 47	46°45′	46°46′
	3	*b*(010)	,,	,,	104 31	85 55	85 50
	4	*r*(021)	,,	,,	61 14	42 38	42 38½
	5	*c*(001)	,,	,,	18 36		
	6	*n*(02$\bar{1}$)	,,	,,	332 5	46 31	46 46
	7	*M*($\bar{1}$10)	290 36	302 10	198 32		69 20
	7	*M*($\bar{1}$10)	62 23	64 45	104 31		62 26½
	8	*z*($\bar{1}$30)	30 54	,,	,,		30 58
	9	*y*($\bar{2}$01)	90 30	99 31	,,		90 32½
	10	*w*($\bar{2}$41)	38 40	,,	,,		38 41½
	11	*p*($\bar{1}$11)	297 45	309 8	,,		62 18
	12	*o*($\bar{1}\bar{1}$1)	64 46	,,	,,		64 53
	11	*p*($\bar{1}$11)	54 16	58 54	18 36		54 17
	9	*y*($\bar{2}$01)	81 8	91 44	,,		81 14
	11	*p*($\bar{1}$11)	315 53½	277 22	61 14		
	9	*y*(20$\bar{1}$)	275 44½	,,	,,		

Digitized by Google

The values of the angles given in the last column have been taken from Dana's *System of Mineralogy*, Sixth Edition. Comparison must be made with the readings of A (after subtraction from 360°, if necessary), except in the case of the zone of reference, when the angular values must be compared with those given in the fourth column.

The last two observations were taken to verify the tautozonality of *p*, *y* and *e*.

Digitized by Google

Note on the Identity of Paralaurionite and Rafaelite.

By G. F. Herbert Smith, B.A.,

Assistant in the Mineral Department of the British Museum.

[Read June 20th, 1899.]

PARALAURIONITE from Laurium was described by the author in the last number of this Magazine,[1] published early in April of this year, and was so called on account of its chemical composition being, as was shown by Mr. G. T. Prior, the same as that of Laurionite. Shortly after, in the number of Groth's *Zeitschrift* published on May 30th, appeared a posthumous paper[2] on new minerals from Chili by the late Professor Arzruni in which was described a new oxychloride of lead, Rafaelite. A comparison of the mean values of the measured angles leaves no doubt as to the identity of the two minerals. The mode of twinning and the optical characters are also the same. The only difference is one of colour: Paralaurionite is white, whereas Rafaelite is violet-red, and shows strong pleochroism. Sufficient material of the latter mineral was not available for quantitative analysis.

The following table compares the means of the measured angles:—

Paralaurionite.		Rafaelite.	
	Observed mean.		Observed mean.
100 : 001	62°47′	100 : 001	62°47′
$\bar{1}00 : \bar{1}01$	77 0	$\bar{1}00 : \bar{1}02$	76 46
$\bar{1}00 : \bar{2}01$	45 24	$\bar{1}00 : \bar{1}01$	45 30
$\bar{1}00 : \bar{4}01$	21 34	$\bar{1}00 : \bar{2}01$	21 57
$\bar{1}00 : \bar{6}01$	13 53	$\bar{1}00 : \bar{3}01$	14 7
100 : 110	67 25	100 : 130	67 28
100 : 111	58 28	100 : 132	58 32
001 : 111	52 39	001 : 132	52 40
001 : 110	79 55	001 : 130	79 55

In addition to these the following forms were found on Rafaelite:—$(\bar{1}08)$, (101), (201), (110), (010), (432). The form (111) of Paralaurionite is (132) of Rafaelite.

---

[1] 1899, XII, 108. The axial ratios are there incorrectly stated. They should be $a : b : c = 2{\cdot}7036 : 1 : 1{\cdot}8019$.

[2] *Zeits. Kryst. Min.* 1899, XXXI, 229.

Digitized by Google

The Identity of Binnite with Tennantite; and the Chemical Composition of Fahlerz.

By G. T. Prior, M.A., F.G.S., and L. J. Spencer, M.A., F.G.S.,
Assistants in the Mineral Department of the British Museum.

[Read January 31st and June 20th, 1899.]

I. Binnite—(*a*) Historical and Introductory; (*b*) Crystallography; (*c*) Physical Characters; (*d*) Associations; (*e*) Chemical Composition; (*f*) Identity of Binnite with Tennantite.

II. Chemical Composition of Fahlerz.

(*a*) Historical and Introductory.
(*b*) Tetrahedrite from "Fresney d'Oisans, Dauphiné."
(*c*) Tetrahedrite from Horhausen, Rhenish Prussia.
(*d*) Tetrahedrite from (Wolfach, Baden)?
(*e*) Proposed new formula for Fahlerz.
(*f*) Test of new formula by reference to the results of previous analyses.

I. Binnite.

(*a*) *Historical and Introductory.*

FEW minerals have had a more varied career than the cubic sulpharsenite of copper—the binnite of Des Cloizeaux—which as small brilliant crystals is of rare occurrence in the white saccharoidal dolomite of the Binnenthal in Switzerland.

Damour,[1] who first mentioned the crystals, gave the locality incorrectly as St. Gotthard, and supposed them to be the same material as the associated massive sulpharsenite of lead ($2PbS.As_2S_3$), which he analysed and called dufrenoysite. According to Damour's paper the crystals had been previously known as grey copper, and that they were thus early correctly identified it is the object of the present paper to prove. Owing to Damour's mistake there has been much confusion in the names binnite

[1] "Notice sur le sulfo-arséniure de plomb de Mont Saint-Gothard (Nouvelle espèce)". *Annales de Chimie et de Physique*, 1845, [iii], XIV, 379-383.

Digitized by Google

and dufrenoysite, and both of them have been applied to each of the two minerals mentioned above; while, owing to the difficulty of distinguishing the several sulpharsenites of lead from the Binnenthal, the name binnite has had at various times at least four different meanings.[1] The distinctive names cuprobinnite and plumbobinnite, introduced by Weisbach,[2] have not been generally followed. It may be mentioned here that the other cubic minerals, galena and blende, from the Binnenthal dolomite have sometimes been mistaken for binnite.

The following three analyses have been made of the cubic copper mineral (binnite); they were in all probability made on very small amounts of material, though in only one case is the actual weight given, namely, 0·0785 gram (Stockar-Escher).

	Uhrlaub.[3]	Stockar-Escher.[4]	Macivor.[5]
Cu	37·74	46·24	46·05
Ag	1·23	1·91	2·43
Fe	0·82	—	—
Pb	2·75	—	—
As	30·06	18·98	18·79
S	27·55	32·73	32·46
	100·15	99·86	99·73
Sp. gr.	4·35—4·69		5·52

From these analyses the following formulæ have been deduced :—

$Cu_2S.CuS.As_2S_3$	S. v. Waltershausen, from Uhrlaub's analysis.
$3Cu_2S.2As_2S_3$	Rammelsberg (1860) ,, ,,
$3Cu_2S.As_2S_3$	Kenngott, from Stockar-Escher's analysis.
$4CuS.Cu_2S.As_2S_3$	Rammelsberg ,, ,,
$3Cu_2S.As_2S_3$	Petersen (*l. c.*) ,, ,,

Of these formulæ, the second, $3Cu_2S.2As_2S_3$, as deduced from the earliest analysis, is the one usually adopted in the text-books, while the two later and more correct analyses are only mentioned.

---

[1] Heusser, *Pogg. Ann.* 1855, XCIV, 334. Des Cloizeaux, *Annales des Mines*, 1885, [v], VIII, 398. Kenngott, *Min. d. Schweiz*, 1866, 373. Petersen, *Ber. Offenbacher Ver. f. Naturk.* 1866, VII, 131.

[2] *Char. Min.* 1880, p. 42.

Sartorius von Waltershausen, *Pogg. Ann.* 1855, XCIV, 120.

[4] Kenngott's *Uebersicht* for 1856-7, 1859, p. 174.

[5] *Chem. News*, 1874, XXX, 103. Small amounts of lead and iron were deducted.

Digitized by Google

These differences are only to be explained by defective analyses made on very small amounts of material, though Trechmann suggested that they might be due to the existence of two cubic copper minerals, the one holohedral and the other tetrahedral. The question as to the holohedral or tetrahedral character of binnite was at one time the subject of much discussion,[1] and it has only recently been decided by Baumhauer[2] and Trechmann[3] that the mineral is really tetrahedral.

The combined crystallographic and chemical results to be described in the present paper show that this much misrepresented mineral, binnite, is nothing more nor less than the arsenical variety of the common fahlerz, and that, except in the more perfect development of the crystals, it does not differ from Cornish tennantite.

The close relationship between binnite and tennantite has been pointed out before. Des Cloizeaux (*loc. cit.*) described binnite as a very arsenical variety of tennantite, but gave the characters which, in his opinion, served to distinguish the two minerals; while Delafosse, in his *Cours de Minéralogie* (1860), actually placed binnite under arsenical grey copper, and pointed out that, according to Stockar-Escher's analysis, it has the composition of Cornish tennantite.

(*b*) *Crystallography.*

Previous descriptions of binnite have been based on only a few crystals, sometimes only one. The present description, which however adds very little to those of Baumhauer and Trechmann, is based on the examination of about 60 crystals and the goniometric measurement of 24 crystals and 28 fragments. A large part of this material was collected by Mr. R. H. Solly during blasting operations in the Binnenthal in the summer of 1898.

Crystals of binnite are brilliant in appearance, and most of the faces are very bright and smooth. In size they rarely exceed 3 or 4 mm. in diameter; the largest crystal, which is slightly elongated in the direction of the trigonal axis, is nearly 1 cm. long. They are rich in faces, and two or more forms are usually more or less equally developed (Fig. 1), so that the crystals are rarely distinctly cubic or dodecahedral in habit, whilst only one crystal exhibited a tetrahedral habit. Frequently

---

[1] Heusser (1856), Sartorius von Waltershausen (1857), Kenngott (1859), Schrauf (1873), Hessenberg (1875), Lewis (1878), Groth (1878).

[2] "Deutliche hemiëdrische Binnitkrystalle," *Zeits. Kryst. Min.* 1893, XXI, 202–207; *Ibid.* 1897, XXVIII, 545–551.

[3] *Min. Mag.* 1893, X, 220–228.

Digitized by Google

the crystals are very irregularly developed, and without removing them from the matrix they are often difficult to decipher unless certain faces can be identified by the characteristic striations and etchings. Even when the crystals are detached they often cannot be properly orientated until two or three zones have been measured on the goniometer, since there is an equality[1] in several of the angles, *e.g.* 100 : 211 = 111 : 110 = 111 : 114 = 85°16′. Usually the crystals occur singly, but sometimes two are grown together in very nearly parallel position. No twinning could be made out.

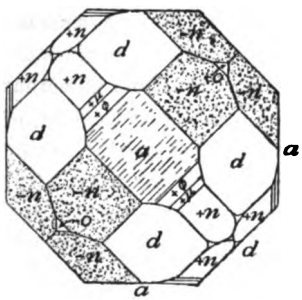


FIG. 1.

The following forms[2] were identified on the 24 crystals measured on the goniometer :—

a {100}. This is present on all crystals either as large or small faces ; these are always bright, and are smooth or faintly striated parallel to their intersection with *o*(111) in the first or positive octant.

d {110}. This is present on all crystals usually as a prominent form. The faces are bright and smooth, and only rarely etched and striated parallel to their intersection with the adjacent cube faces.

+*o* {111}. Small and bright; not common. On the single crystal, which is tetrahedral in habit, it is present as a large face striated parallel to its intersections with the cube planes.

---

[1] *See* A. Schmidt, "Wiederkehr gleicher Flächenwinkel im regulären Krystallsysteme," *Zeits Kryst. Min.* 1896, XXV, 477 ; and *Math. és term.-tud. Értesitö*, 1895, XIII, 331.

[2] The letters used for the forms are those of Dana (*System of Min.* 1892, 6th Edit.).

Digitized by Google

$-o\{1\bar{1}1\}$. This is more frequently present than $+\{111\}$. The faces are small and bright, and often appear to have been developed by the etching of $-n\{2\bar{1}1\}$.

$+n\{211\}$. Is present on all crystals, and is often a prominent form. It is very bright and smooth, but is sometimes faintly striated parallel to its intersection with $+o\{111\}$, especially when several other $\{hkk\}$ forms are present in the same octant.

$-n\{2\bar{1}1\}$. Is also present on all crystals either as large or as narrow planes. Usually the faces, though quite even, are dull and like ground-glass in character, giving no reflected image. Rarely they are bright and smooth, or with a slight reddish tarnish. Sometimes the pittings are deep, and light is then seen to be reflected from numerous spots in the position of $-o\{1\bar{1}1\}$, and, to a lesser extent, of $d\{110\}$ and $a\{100\}$.

$+\phi\{611\}$. A small bright face striated parallel to its intersection with the cube; present on most crystals, sometimes rather large.

$+\{hkk\}$. Some crystals show in the positive octants banded zones of bright narrow faces between the cube and octahedron; they are striated and sometimes rounded parallel to their intersections with these faces. The following angles are a selection of the best of the numerous ones measured on the several crystals, the reflections being from distinct planes:—

$+\{hkk\}$.	Calcd. to (100).	Measd. (L.J.S.).	(Observers.)[1]
25.1.1	3°14′	3°18′. Large smooth plane.	—
18.1.1	4 29½	4 28, 4°30′. On two crystals.	—
14.1.1?	5 46	5 40.	—
12.1.1	6 43	6 40, 6°37′.	(Baumhauer, T.).
51.5.5	7 53½	7 53. Fairly large.	—
10.1.1	8 3	8 2, 8°11′.	(Hessenberg, L.T.B.).
911	8 56	8 54.	(Trechmann).
811?	10 1½	9 46, 10°21′.	,,
31.4.4	10 20½	10 21.	—
711	11 25	11 25, 11°29′.	(Lewis, T.B.).
611	13 16	13 15, etc.	(Heusser, Groth, L.B.T.).
411	19 28	19 24, 19°28′, 19°16′, 19°21′.	(Hessenberg, L.B.T.).
311	25 14	25 13, 25°23′, 25°12′.	(Trechmann, B.).
522	29 30	29 18.	(Trechmann).
25.12.12	34 10	34 11½.	—
211	35 16	35 16, etc.	(All authors).

[1] T = Trechmann; L = Lewis; B = Baumhauer.

Digitized by Google

$+r\{332\}$. Small bright faces striated or rounded parallel to the edges $[n, n]$, which they truncate. On five crystals.

$-r\{3\bar{3}2\}$. Small dull faces of the same character as $-n\{2\bar{1}1\}$, the edges of which they truncate; striated parallel to their intersection with $-o\{1\bar{1}1\}$, *i.e.* perpendicular to the edge $[-n, -n]$. On five crystals, but not on those with $+r\{332\}$.

$+\Sigma\{552\}$. Small bright faces, sometimes striated and rounded parallel to their intersections with $+o\{111\}$. On four crystals. Besides those from $+r$ and $+\Sigma$, there are other scattered reflections in the zone between (111) and (110) in the rounded positive octants.

$e\{210\}$. } As bright narrow roundings on the edges formed by the
$f\{310\}$. } cube and the dodecahedron. {210} is new for "binnite."

$+s\{321\}$. As a small bright face striated parallel to its intersection with $+o\{111\}$. More often as a narrow rounding on the edge [211, 110].

$+G\{543\}$. } Several small bright planes with curved contours in the
$+\{965\}$. } smooth rounded area in the positive octant of one crystal. The faces (211), (965), (543), (332), (453), (695), (121) form a zone. These two forms are new for fahlerz.

	Calc^{d}.	Meas^{d}. (L.J.S.)
543 : 453	11°28½′	11°32′, 11°28′, 11°32′.
965 : 695	20 51	20 12.
965 : 332	10 15½	10 10, 10°0′.

From the characters given above, it will be seen that there are several indications of the tetrahedral symmetry, namely:—

(1). The striation of the cube planes parallel to their intersections with the positive tetrahedron.

(2). The faces of $+n\{211\}$ and $+r\{332\}$ are bright and smooth in the positive octants, whilst the complementary forms $-n\{2\bar{1}1\}$ and $-r\{3\bar{3}2\}$ are usually dull and rough.

(3). The development in the positive octants of numerous $\{hkk\}$ forms.

(4). Hexakistetrahedral forms $\{hkl\}$ occur in the positive octants. Baumhauer's $\{9\bar{4}1\}$ is the only one in the negative octant.

(5). The bright roundings of the edges and coigns in the positive octants, which are sometimes so pronounced that the whole area has the appearance of a polished knob. Only rarely are the crystals rounded in the negative octants.

Digitized by Google

These points are shown diagrammatically in Fig. 1.[1] It is to be noticed that the hemihedral character is not often apparent from the relative sizes and development of the faces in adjacent octants, and as a rule it seems only to have been brought out by the subsequent etching of the crystals. Thus on some crystals $+n\{211\}$ and $-n\{2\bar{1}1\}$ are of the same size, and are equally bright and smooth, so that the symmetry is apparently holohedral. The effect of the etching has been to roughen the faces in the negative octants, and to round the edges and coigns with bright prærosion[2] planes in the positive octants. Many of the small faces noted above may be only due to prærosion.

It should be pointed out that the indications of the hemihedrism given above do not as a rule apply to fahlerz from other localities, as for example those described in Sections II. (*b*)—(*d*) below, and that the distinction between positive and negative forms is purely arbitrary, and cannot be compared for different occurrences.

(*c*) *Physical Characters.*

The colour is iron-black, with a brilliant metallic lustre and an almost velvety appearance. The streak (on paper) is dull and is usually chestnut-brown, but it varies in shade for different crystals, and is sometimes dark brown with a tinge of purple, whilst for two crystals it is black. In the first case the streak on the crystals is cherry-red, and the fine powder is dark purple. Very thin splinters of the crystals with the chestnut-brown streak are translucent and crimson by transmitted light, and crimson flashes may sometimes be seen on the fractured surfaces. The mineral is optically isotropic. Crystals with the black streak are opaque. The colour of the streak appears to depend on the amount of iron in the mineral (p. 192).

A marked feature is the very good and brilliant conchoidal fracture. The mineral is very brittle. H.=4¼. Sp. gr. (weight of 1 c.c.) of the material analysed is 4·62 at 18° (as determined on 0·4878 gram) for the crystals with the chestnut-brown streak, and 4·598 for those with the black streak.

---

[1] This is much the same as Baumhauer's Fig. 9, Plate IX, in *Zeits. Kryst. Min.* 1897, XXVIII.

[2] A. Hamberg, *Bihang Svenska Vet.-Akad. Handl.* 1887, XIII (2), No. 4; Abstract in *Zeits. Kryst. Min.* 1889, XV, 84.

Digitized by Google

(*d*) *Associations.*

Usually the crystals of binnite occur singly, though sometimes there are as many as a dozen crystals in the same cavity. They seem to be most frequent in those parts of the white saccharoidal dolomite which are veined with coarsely crystalline yellowish dolomite. The crystals rest on the colourless crystallised dolomite lining the cavities, or sometimes on crystals of blende. In one case the crystals of blende and binnite were in very nearly parallel position. Small crystals of pyrites encrust and are partly embedded in the binnite. Sartorite and realgar are frequently present.

(*e*) *Chemical Composition.*

The first of the following two analyses was made on eleven of the measured binnite crystals, of which the streak was chestnut-brown. The crystals were broken up, and the fragments carefully selected. The method of analysis was by decomposition in chlorine, as described in the case of andorite.[1] The arsenic was determined in the solution of the volatile chlorides by precipitation with magnesia mixture. The chlorine appeared to have very little action upon the mineral in the cold. The results of the analysis[2] made on 0·8101 gram were as follows (G. T. P.):

			Atomic ratios.	
Cu	...	49·88	·7895	6
Ag	...	1·87	·0174	
As	...	19·04	·2558	1·902
Pb	...	0·17	·0008	0·006
Fe	...	1·11	·0200	0·148
S	...	27·60[3]	·8671	6·446
		99·62		
Sp. gr.	...	4·62		

The numbers correspond approximately to the formula :—

$$3Cu_2S.As_2S_3 = Cu_3AsS_3.$$

The sulphur is somewhat too high, the atomic ratio calculated to convert the other elements into sulphides being as low as 0·8080.

---

[1] *Min. Mag.* 1897, XI, 290.

[2] The atomic weights used throughout this paper are those given by F. W. Clarke (*Smithsonian Miscell. Collections*, 1897, No. 1075).

[3] Mean of 27·56 and 27·65, the latter by fusing another portion (0·1972 gram) of the same sample of material with sodium carbonate and potassium nitrate.

Digitized by Google

A second partial analysis was made on two crystals, of which the streak was black instead of chestnut-brown, in order to discover, if possible, on what this difference of streak depended. The results of the analysis made on 0·1390 gram were (G. T. P.):—

			Atomic ratios.	
Cu	...	44·12	·6991	6
Ag	...	4·77	·0445	
As	...	[20·49]	·2690	2·171
Fe	...	3·68	·0662	0·534
S	...	26·94	·8463	6·830
		100·00		
Sp. gr.	...	4·598		

The numbers correspond closely to the formula:—

$$[3(Cu,Ag)_2S.As_2S_3]+\tfrac{1}{11}[6FeS.As_2S_3].$$

The results of this analysis, when considered in connection with Rose's analyses of fahlerz (see pp. 204-6), and the three tetrahedrite analyses given in the present paper, suggest that the black streak is due to the presence of iron in larger amount than three per cent., and that the red streak has no connection with the amount of silver (as implied in Dana's *System of Mineralogy*) or with the amount of zinc (as stated in Naumann-Zirkel's *Mineralogie*).

(*f*) *Identity of Binnite and Tennantite.*

The crystallographic and chemical investigation of binnite, the details of which are given in the preceding paragraphs, shows that neither physically nor chemically is there any essential difference between binnite and tennantite.

The crystals of the Binnenthal mineral possess the same degree of symmetry as the Cornish tennantite, and only differ in their more perfect development, being brighter and richer in faces. W. Phillips,[1] who first described tennantite in 1819, gave the forms: $a\{100\}$, $d\{110\}$, $o\{111\}$, $n\{211\}$ and $\beta\{322\}$; and in the MS. catalogue (by Prof. Miers) of the specimens of Cornish tennantite in the British Museum collection the forms are: $a\{100\}$, $d\{110\}$, $+o\{111\}$, $-o\{1\bar{1}1\}$, $+n\{211\}$, $-n\{2\bar{1}1\}$, $+r\{332\}$, and narrow planes near $+\phi\{611\}$. All these forms occur on crystals of binnite.

---

[1] *Journ. Lit. Sci. & Arts* (*Roy. Inst.*), 1819, VII, 95; and Phillips' *Min.* it.

Digitized by Google

The dull crystals of Cornish tennantite are usually much intergrown with each other and with other minerals, so that they do not show the same bright lustre and perfect conchoidal fracture as binnite. Otherwise the physical characters are the same: thus Cornish tennantite has sp. gr.[1]=4·69 and H=4, and shows the same variation in the colour of the streak from dark red to black.

That they are also chemically identical is seen by comparison of the above analyses (pp. 191-2) with the following three analyses of Cornish tennantite:—

	Kudernatsch.[2]	Rammelsberg.[3]	Wackernagel.[3]	$3Cu_2S.As_2S_3$.	$4Cu_2S.As_2S_3$.
Cu	48·94	51·62	48·68	52·70	57·60
As	19·10	19·03	20·53	20·72	16·98
Fe	3·57	1·95	3·09	—	—
S	27·76	26·61	26·88	26·58	25·42
	99·37	99·21	99·18	100·00	100·00
Sp. gr.	—	—	4·69	—	—

II. Chemical Composition of Fahlerz.

(*a*) *Introduction.*

The chemical formula generally accepted for fahlerz (tetrahedrite and tennantite) and given in the text-books is $4Cu_2S.(Sb,As)_2S_3$, or generally $4R''S.R'''_2S_3$, where $R''=Cu_2,Ag_2,Fe,Zn$, &c., and $R'''=Sb,As,Bi$; the divalent atoms Fe,Zn being supposed to isomorphously replace Cu_2. This is the formula which was originally proposed by H. Rose in 1829, as best expressing the result of seven analyses of fahlerz from various localities made on pure crystallised material.

Very few, however, of the published analyses of fahlerz agree at all closely with this formula, and many of them approach much more nearly to the 3 : 1 formula $3R''S.R'''_2S_3$. One of the latest analyses of tetrahedrite (see analysis 18, p. 218) corresponds to the formula $7RS.2Sb_2S_3$ or $4RS.Sb_2S_3+3RS.Sb_2S_3$. This want of agreement of most of the analyses with the ordinary text-book formula has received expression in the latest

[1] Wackernagel (1860) and Baumert (1858).

[2] *Pogg. Ann.* 1836, XXXVIII, 397.

[3] Rammelsberg's *Handb. d. Min.-Chem.* 1860, p. 88. Other analyses of Cornish tennantite are given by R. Phillips (1819), Hemming (*Phil. Mag.* 1831, X, 157), and vom Rath and Baumert (*Sitz.-ber. niederrh. Ges. Bonn*, 1858, XV, p. LXXII).

Digitized by Google

supplement (1895) to Rammelsberg's *Mineralchemie*, where the composition of fahlerz is given as a mixture of $3RS.Sb_2S$ and $4RS.Sb_2S_3$.

It will be found as a general rule that the analyses which approach most closely to the ordinary 4 : 1 formula are those in which the percentages of divalent elements (Fe,Zn) are high. On the other hand, whenever an analysis shows a comparatively simple composition, with only small percentages of divalent elements, the numbers correspond very closely to the 3 : 1 formula. This is the case with the first analysis of binnite (p. 191), and also with the analyses of Cornish tennantite, quoted on p. 198, as is seen by comparing the numbers with those corresponding to the two formulæ $3Cu_2S,As_2S_3$ and $4Cu_2S.As_2S_3$ given on p. 193. Kudernatsch was only able to make his analysis (p. 193 above) accord with the 4 : 1 formula by considering part of the copper to be present as CuS instead of Cu_2S.

The tennantite from Rudelstadt, Silesia, of which the analysis (No. 10, p. 209) corresponds to the 3 : 1 formula, was on that account described by Websky as a new species under the name of "julianite." "Annivite," "studerite," and the more recent "falkenhaynite"[1] are other names which have been applied to fahlerz, of which the analyses accord more nearly with the 3 : 1 than with the ordinary text-book formula. In some of the text-books many of these are referred to the obscure orthorhombic (?) mineral stylotype, to which the formula $3(Cu_2,Ag_2,Fe)S.Sb_2S_3$ has been assigned.

In the case of tetrahedrite proper the percentage of iron or zinc seldom sinks below 3. An analysis (No. 11, p. 209), however, by Nilson, of the so-called "aphthonite" from Gärdsjö, Wermland, shows only fractional percentages of both iron and zinc. As shown on p. 209, the numbers obtained in this analysis agree almost perfectly with the 3 : 1 formula.

There is thus strong evidence in favour of the view that the true formula for the simple sulphantimonite or sulpharsenite of copper is $3Cu_2S.(Sb,As)_2S_3$. The iron and zinc appear to be the disturbing elements which cause the analyses to approach the 4 : 1 formula of Rose.

In 1870 Petersen, in a short note on the formula of sulpho-salts,[2] actually proposes the 3 : 1 formula for fahlerz, and suggests that variations from this are due to the presence of impurities such as iron- and copper-pyrites in the material analysed. The well-known intimate asso-

[1] Scharizer, *Jahrb. geol. Reichs.* 1890, XL, 483.

[2] *Neues Jahrb. f. Min.* 1870, 455–9.

Digitized by Google

ciation and parallel intergrowth of copper-pyrites and blende with tetrahedrite, as described by Sadebeck, Becke and others, lend some support to this view. The frequent occurrences of tetrahedrite in which the fracture is granular and interrupted, instead of being perfectly smooth and conchoidal, also suggests that most crystals are not homogeneous, but that they are intimately intergrown with copper pyrites, which indeed can in many cases be seen as minute yellow specks throughout the whole material. In choosing specimens for the present analyses, very few were found which were at all suitable for the collecting of pure material.

The idea, however, that the iron in fahlerz is due to impurities of iron- or copper-pyrites is not supported by an examination of the hitherto published analyses. Calculations of the atomic ratios show that, as a rule, the total sulphur found corresponds with the amount calculated to convert the other elements into sulphides, the iron being supposed to be present as FeS and not as FeS_2.

That the sulphides of the divalent metals might be present in fahlerz in another form of combination with the sulphides of antimony and arsenic than the sulphides of the monovalent metals has been advocated by Kenngott in an elaborate paper on the formula of fahlerz.[1] As the result of his calculations of a large number of analyses he was led to propose the general formula $4R'_2S.R'''_2S_3+x[3R''S.R'''_2S_3]$. He obtained this result, however, by starting with the assumption that the correct formula for the simple mineral was $4Cu_2S.(Sb,As)_2S_3$, and by referring analyses which gave the 8 : 1 formula to "julianite," which he regarded as a distinct species.

In this state of uncertainty as to the true formula of fahlerz, the present investigation was undertaken in order to see if the analysis of pure tetrahedrite of simple composition would confirm the result obtained in the case of binnite, and substantiate the 8 : 1 in preference to the generally accepted 4 : 1 formula; and to discover, if possible, in the case of specimens of more complex character, in what way the iron and zinc enter into the composition of the mineral.

Three specimens from different localities were selected for analysis. These were chosen on account of their comparative freedom from impurities, such as iron- and copper-pyrites, and the apparent homogeneity of the crystals as indicated by the perfectly smooth and brilliant conchoidal fracture. This latter character was the one chiefly relied upon as a guarantee of purity. In the analyses only crystal fragments showing an

[1] Kenngott. "Ueber die Fahlerzformel." *Neues Jahrb. f. Min.* 1881, II, 228-248.

Digitized by Google

uninterrupted conchoidal fracture were used. The greatest care was taken in selecting material absolutely free from all visible impurities, each fragment being picked out under the lens and then examined under a microscope, the 1in. objective of which was fitted with a Lieberkuhn.

(*b*) *Tetrahedrite from "Fresney d'Oisans, Dauphiné."*[1]

This specimen is described in the Heuland sale catalogue for May 3rd, 1833, as: "895. An UNIQUE specimen of grey Copper Ore from Fresney, Oisans, Dauphiné, with Rock-crystals and Carbonate of Iron."

On the matrix is a fine isolated crystal, measuring 4 cm. along the octahedral edge, which is by far the largest and best in the large suite of tetrahedrites in the British Museum collection.

Crystallography.—The two tetrahedra $+o\{111\}$ and $-o\{1\bar{1}\bar{1}\}$ are equally developed, so that the crystal has the appearance of a regular octahedron (Fig. 2); but while $+o\{111\}$ is bright and smooth, the com-

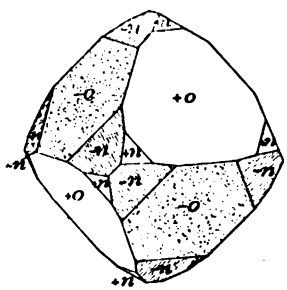


FIG. 2.

plementary tetrahedron $-o\{1\bar{1}\bar{1}\}$ is dull and rough, being covered with numerous minute triangular pyramids reflecting light with the planes of the rhombic dodecahedron. The only reflections in the positions of the faces of $-o\{1\bar{1}\bar{1}\}$ are from the small triangular truncations of these pyramids; these small planes are smooth, but rather dull. The two triakistetrahedra, $+n\{211\}$ and $-n\{2\bar{1}\bar{1}\}$, are well developed; the former is bright and smooth, and very faintly striated parallel to its intersection with the positive tetrahedron; the latter, which is slightly larger, is dull

[1] The authority for this locality is the Heuland catalogue. Two other specimens of tetrahedrite from the Heuland collection, and now in the British Museum, which are exactly similar in appearance and matrix to the specimen now described, are, according to the Heuland catalogue, from Baigorry, Basses-Pyrénées. The latter occurrence is mentioned by Romé de l'Isle (1773), and is described at length by Prof. Lacroix (*Min. de France*, 1897, II, p. 724). Lacroix only just mentions the specimens of tetrahedrite as being labelled Fresney d'Oisans.

Digitized by Google

and deeply striated perpendicular to its intersection with the negative tetrahedron, *i.e.* parallel to its intersection with the rhombic dodecahedron. The rhombic dodecahedron is represented by bright narrow planes truncating the edges $[+o, -o]$, or oscillating with $-n\{2\bar{1}1\}$ and giving rise to the striations on these faces. With the contact goniometer the angle $on = 111 : 211$ was measured as 20° (calculated 19°28′).

Physical Characters.—The colour is steel-grey, with bright metallic lustre; the streak is dull and dark brown, with a tinge of purple. The mineral is opaque, even in thin splinters. Fracture conchoidal, and very bright and smooth. Very brittle; H = 4½. Specific gravity of the material analysed 4·921 at 17°.

Associations.—Although the crystal is in places slightly cracked and etched, yet the material is perfectly fresh in appearance. The cracks are filled with films of limonite together with a little malachite and chessylite, and these substances are in places present as films on the surface of the crystal. On the fractured surfaces of the crystal are one or two yellow marks which seem to be films of copper- or iron-pyrites.

The matrix consists mainly of large rhombohedra of chalybite altered to limonite. On this is the large crystal of tetrahedrite, with a small crystal and a little massive tetrahedrite. Of later formation than this are clear colourless prisms of quartz. All these minerals are coated in places with limonite, and this in turn is coated with thin crusts of green malachite and blue crystalline chessylite. After the deposition of: (1) chalybite, (2) tetrahedrite, and (3) quartz, the material seems to have been slightly crushed and the chalybite altered to limonite, followed by an etching and slight surface alteration of the tetrahedrite.

Chemical Composition.—Plenty of pure material for analysis could be collected without difficulty from the fractured surface of the large crystal. Before being picked over, the fragments were boiled in hydrochloric acid to remove limonite and copper carbonates.

The result of the analysis was as follows (G. T. P.):—

			Atomic ratios.		Calcd. for $3Cu_2S.Sb_2S_3$.
Cu	...	45·39	·7192	6	46·83
Sb	...	28·85	·2414	2·017	29·55
As	...	trace			—
Fe	...	1·32	·0238	·199	—
Pb	...	0·11	·0005	·004	—
S	...	24·48	·7690	6·424	23·62
		100·15			100·00
Sp. gr.	...	4·921			

Digitized by Google

Weight of material used in analysis = 0·6395 gram and (for separate sulphur determination) 0·3672 gram. The atomic ratio of the total sulphur calculated for the sulphides on the assumption that the iron is present as iron-pyrites is ·7698.

Deducting the iron and lead as FeS_2 and PbS, the atomic ratios for Cu : Sb : S = 6 : 2·017 : 6·022, which correspond almost exactly to the formula $3Cu_2S.Sb_2S_3 = Cu_3SbS_3$.

(c) *Tetrahedrite from Horhausen, Rhenish Prussia.*

The beautiful crystals of tetrahedrite from Horhausen in Rhenish Prussia have been described[1] several times, but the material from this locality does not appear to have been analysed. Since the crystals are so perfectly developed, have a good conchoidal fracture, and are not intimately associated with copper-pyrites, they appeared to form suitable material for establishing the tetrahedrite formula. The specimen selected for detailed examination was the one showing the least amount of blende and no copper-pyrites on the free surface.

Crystallography.—The brilliant crystals have all their faces bright and smooth; they measure up to 5 mm. across, but are usually much smaller.

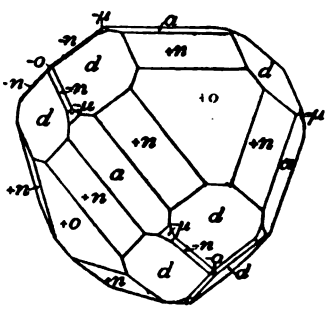


Fig. 3.

The habit of the crystals is tetrahedral, with large faces of the rhombic dodecahedron (Fig. 3). The forms present on six measured crystals giving excellent readings are, in order of predominance :—

---

[1] C. Klein, *Neues Jahrb. f. Min.* 1871, 493. A. Sadebeck, *Zeits. Deutsch. geol. Ges.* 1872, XXIV, 458. G. Seligmann, *Zeits. Kryst. Min.* 1877, I, 335. G. vom Rath, *Zeits. Kryst. Min.* 1881, V, 258. P. Groth, *Min.-Sammlung, Strassburg* 1878, p. 66.

Digitized by Google

$+o\{111\}$. This is usually smooth, but is sometimes represented by bright vicinal faces $\{hhl\}$ $(h > l)$ deeply striated parallel to their intersections with *o* and *d*.

$d\{110\}$. Bright and smooth.

$+n\{211\}$. Bright and smooth.

$a\{100\}$. Bright and smooth. Faintly striated parallel to its intersection with $+o\{111\}$.

$-n\{2\bar{1}1\}$. Narrow; not so bright as $+n$, and sometimes rather rough.

$-\mu\{4\bar{1}1\}$. Bright and smooth; small.

$-o\{1\bar{1}1\}$. Bright and smooth; very small.

$+\mu\{411\}$. Observed once as a narrow plane.

$-r\{33\bar{2}\}$. Observed once as a very narrow rounding between two planes of $-n\{2\bar{1}1\}$.

The above forms, with the exception of the last two, are present on all crystals, and there is very little variation in the relative sizes of the faces on different crystals. The crystals are sometimes grouped together in more or less parallel position, or small crystals are partly embedded in large ones, but no definite orientation between two crystals could be discovered.

There is no marked difference between the surface characters of the faces in adjacent octants, nor could any difference be developed in attempts to etch the crystals with bromine water or with nitric acid.

Physical Characters.—The colour is iron-black, with brilliant metallic lustre. Streak dark brown with a purplish tinge. Only the thinnest flakes are crimson by transmitted light; the mineral is then seen to be optically isotropic. Fracture conchoidal, bright and smooth, but not quite so good as that of binnite; where the crystals are intergrown close to the matrix the fracture is only sub-conchoidal. Brittle; $H = 4\frac{1}{4}$. Sp. gr. of the material analysed 4·969 at 17°.

Associations.—The matrix consists of massive buff-coloured chalybite with milky quartz in veins and patches; it encloses a few specks of copper pyrites and of a black mineral which is probably massive tetrahedrite. On the free surface are the following crystallised minerals in the order of formation: (1) Lenticular crystals of chalybite with one or two quartz crystals. (2) Galena in dull well-developed octahedra, with small cube planes. (3) Tetrahedrite, which has grown over, and is intimately associated with, the galena. (4) A few small crystals of reddish-brown blende.

Digitized by Google

Chemical Composition.—The material collected for analysis was boiled with strong hydrochloric acid to remove galena before being picked out under the lens and microscope.

The result of the analysis is as follows (G. T. P.):—

			Atomic ratios.	
Cu	...	41·55	·6582	6
Sb	...	28·32	·2370	2·20
Bi	..	0·83	·0046	
As	...	trace		
Fe	...	1·02	·0184	0·55
Zn	...	2·63	·0405	
Pb	...	0·62	·0030	
S	...	24·33	·7642	6·95
		99·30		
Sp. gr.	...	4·969		

Weight of material used in analysis 0·4856 gram and (for separate sulphur determination) 0·2808 gram.

The calculated atomic ratio of the total sulphur, assuming iron present as FeS, is ·7530. After deducting $3Cu_2S.Sb_2S_3$, the atomic ratios of the residue are—

$$Sb : (Fe,Zn) : S = \cdot 2 : \cdot 55 : \cdot 95,$$

which correspond approximately to the formula $6(Fe,Zn)S.Sb_2S_3$. The correspondence would have been closer but for a slight loss of zinc during the filtering of the sulphide. The combined formula is therefore:

$$[3Cu_2S.Sb_2S_3] + \tfrac{1}{10}[6(Fe,Zn)S.Sb_2S_3].$$

(*d*) *Tetrahedrite from (Wolfach, Baden)*[1]*?*

Crystallography.—The crystals are tetrahedral in habit (Fig. 4), with large $+o\{111\}$, and smaller $+n\{211\}$, $+\mu\{411\}$ and $a\{100\}$; and on the acute trigonal coigns very small bright $-o\{1\bar{1}1\}$ and $d\{110\}$. The faces of $a\{100\}$ and $+\mu\{411\}$ are deeply striated parallel to their mutual inter-

[1] This specimen has been for many years in the British Museum collection, and was labelled "Andreasberg, Harz" by the late Mr. T. Davies, but the associations are so unlike those described in the literature of minerals from the Harz (Luedecke, *Min. d. Harzes*, 1896) that this locality must be considered as doubtful. On the other hand, on account of the remarkable agreement in every particular with Sandberger's (*Neues Jahrb. f. Min.* 1869, pp. 301, 297; *Untersuch. über Erzgänge*, 1885, II, pp. 288, 283) description of tetrahedrite from the Wenzel Mine near Wolfach in Baden, we have ventured to suggest that the specimen in all probability came from this locality.

Digitized by Google

sections, while the striations on $+n\{211\}$ in the same direction are much less marked. The faces are bright, but are roughened by curious granular and vermiform markings, so that they give poor reflections; besides these minute markings, there are a few larger thread-like elevations, which

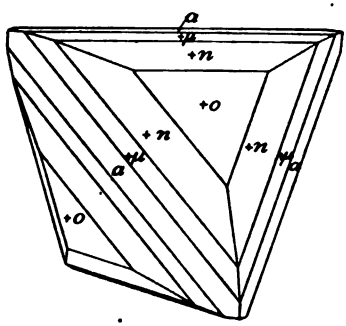


FIG. 4.

often run across from one crystal to another; these suggest healed-up cracks in the crystals. All the crystals are of exactly the same habit and easy to decipher, so that only one was measured on the goniometer. In size the crystals average about 0·5 cm. along the tetrahedral edge, the largest being 1·5 cm.

Physical Characters.—The colour is steel-grey to iron-black, and the streak black (or very dark brown); opaque. Brittle; H=4. The fracture is conchoidal, but in places sub-conchoidal to uneven, especially where the crystals are much intergrown close to the matrix.

Sp. gr. of the material analysed 5 047 at 22°.

Associations.—The matrix is a dirty yellow mixture of dolomite and a scaly talcose mineral, enclosing one or two crystals of pyrites and quartz and some massive tetrahedrite (?). On the free surfaces are two or three crystals of galena (cubo-octohedra with small $d\{110\}$) intimately associated with the crystals of tetrahedrite, and apparently formed at the same time. These crystals are partially embedded in white barytes, which, as shown by the cleavages, preserves its crystalline continuity over a considerable area. This barytes and some of the dolomite have crystallised around the tetrahedrite, and were the latest minerals to be formed; they present no natural faces, but only cleavage surfaces, through which the crystals of tetrahedrite project.

With the lens one or two minute crystals of what appeared to be copper-pyrites were observed on a crystal of tetrahedrite; but when the surface of the tetrahedrite crystals was illuminated with the aid of a Lieberkuhn

Digitized by Google

and examined under the microscope, minute yellow crystals were more often seen. The fractured surfaces of the tetrahedrite rarely showed a bright yellow tarnish due to a film of copper- or iron-pyrites.

Chemical Composition.—The result of the analysis was as follows (G. T. P.):—

			Atomic ratios.	
Cu	...	30·56	·4842	6
Ag	...	15·26	·1425	
Sb	...	27·78	·2320	2·21
As	...	trace		
Fe	...	3·51	·0631	·60
Zn	...	trace		
Pb	...	0·05	·0002	
S	.	23·15	·7272	6·96
		100·26		
Sp. gr.	...	5·047		

Weight used = 0·8911 gram, and 0·4447 gram for the sulphur determination. The atomic ratio of the total sulphur calculated for sulphides, on the assumption that iron is present as FeS, is ·7247. After deducting $3(Cu,Ag)_2S.Sb_2S_3$, the atomic ratios for the residual

$$Sb : (Fe,Zn) : S = ·21 : ·6 : ·97,$$

which correspond very closely to the formula $6(Fe,Zn)S.Sb_2S_3$. The combined formula is therefore the same as in the case of the Horhausen specimen:

$$[3(Cu,Ag)_2S.Sb_2S_3] + \tfrac{1}{10}[6(Fe,Zn)S.Sb_2S_3].$$

The above analysis resembles Rose's (see No. 2, p. 205) and the earlier analysis of Klaproth[1] of tetrahedrite from the Wenzel Mine, Wolfach, Baden.

(*e*) *Proposed new formula for Fahlerz (Tetrahedrite and Tennantite).*

$$3R'_2S.R'''_2S_3 + x[6R''S.R'''_2S_3],$$

where R′ = Cu,Ag; R″ = Fe,Zn; R‴ = Sb,As,Bi; and x is a small fraction, often = $\frac{1}{10}$ and $\frac{1}{5}$, but rising to $\frac{1}{2}$ in the case of the highly ferriferous tetrahedrite, "coppite."

The result of the analysis (p. 197) of the mineral from Dauphiné containing little iron or zinc served to substantiate the conclusion which had been arrived at from the analysis of binnite and the older analyses of tennantite and tetrahedrite of simple composition that the true formula for fahlerz proper is $3(Cu,Ag)_2S.(Sb,As)_2S_3$.

[1] *Beiträge*, 1807, IV, 71.

Digitized by Google

In the case of the last two analyses of specimens of less simple composition, if FeS and ZnS be taken as isomorphously replacing Cu_2S, the numbers obtained, like those of most analyses of tetrahedrite, correspond to a mixture of $3RS.Sb_2S_3$ and $4RS.Sb_2S_3$.

If, however, the above conclusion is accepted, that the true formula for the simple sulphantimonite of copper is $3Cu_2S.Sb_2S_3$, then the last two analyses serve to indicate in what way the iron and zinc enter into the composition of the more complex varieties of the mineral, for it is only necessary to deduct from the atomic ratios of the elements the whole of the Cu and Ag with part of the Sb,As and S to form $3(Cu,Ag)_2S.(Sb,As)_2S_3$, in order to see what ratio the (Fe,Zn) bears to the residual (Sb,As) and S.

As seen on pp. 200 and 202, application of this process to the last two analyses indicates that the Fe and Zn enter into the composition of the mineral as $6(Fe,Zn)S.Sb_2S_3$, the group 6(Fe,Zn)S and not 3(Fe,Zn)S isomorphously replacing $3Cu_2S$.

The new formula receives its theoretical explanation in the suggestion which is tentatively put forward that in the crystallisation of the normal sulphantimonite of copper, sulphides of iron and zinc in small amount may be drawn into the composition of the mineral in the form $(Fe,Zn)_6S_6.Sb_2S_3$, as the combination with sulphide of antimony most nearly approaching in structure to $Cu_6S_3.Sb_2S_3$. In fahlerz therefore $(Fe,Zn)_6S_6$ is supposed to isomorphously replace Cu_6S_3, owing to the predominating influence or "mass effect"[1] of the metallic atoms. The theory is thus an extension of the idea, which appears to be now gaining ground, that in many cases it is the number of atoms irrespective of their valency which is of importance in isomorphism[2] (*e.g.* the felspars $NaAlSi_3O_8$ and $CaAl_2Si_2O_8$; calcite and sodium nitrate).

(*f*) *Test of the new formula by reference to the results of previous analyses.*

The following eighteen analyses on which to test the new formula are arranged in order of date, beginning with those of Rose,[3] from which the original 4 : 1 formula was deduced.

---

[1] Compare Penfield, *Amer. Journ. Sci.* 1896, II, 8; Abstract *Min. Mag.* XI, 2?5. *Ibid.* 1899, VII, 123; Abstract this No. p. 217.

[2] Hamberg, *Geol. För. Förh.* 1890, XII, 598; Penfield and Foote, *Amer. Journ. Sci.* 1897, L, 110.

[3] Two out of Rose's seven analyses are not included, as they show intermixed matrix, and large percentages of both arsenic and antimony, the separation of which was by an imperfect method.

Digitized by Google

They are chosen for the most part as having been made on pure material and by good methods of analysis. As a rough test of the value of the analysis, in each case, to the atomic proportion of sulphur found is appended the atomic proportion of sulphur calculated to convert the other elements into sulphides (Cu_2S,FeS,Sb_2S_3 etc.).

After each analysis are given the atomic ratios of R″ (Fe,Zn), and of the residual R‴ (Sb,As,Bi) and S left after deducting the whole of the copper and silver and part of the R‴ and S to form $3(Cu,Ag)_2S.(Sb,As)_2S_3$. According to the new formula, in a perfect analysis the atomic ratios of R″ and the residual R‴ and S should be R″ : R‴ : S = 6 : 2 : 9.

In the cases where the colour of the streak is mentioned, the analyses will be seen to confirm the suggestion made on p. 192 that in fahlerz the black streak is due to the presence of iron in larger amount than 3 per cent.

(1). *Tetrahedrite from Zilla, near Clausthal, Harz.*

H. Rose (*Pogg. Ann.* 1829, XV, 578). Tetrahedral crystals with copper-pyrites and galena. Streak, very dark red.

				Atomic ratios.
Cu	...	34·48	·5468	6
Ag	...	4·97	·0464	
Sb	...	28·24	·2363	2 + ·392
Fe	...	2·27	·0408	1·278
Zn	...	5·55	·0855	
S	...	24·73	·7769 (Calcd. ·7771)	6 + 1·864
		100·24		

Residual R″ : R‴ : S = 1·278 : ·392 : 1·864
= 6·5 : 2 : 9·5

corresponding to $6RS.R_2S_3 + \cdot 5RS$.

Approx. formula : $[3R_2S.Sb_2S_3] + \frac{1}{2}[6RS.Sb_2S_3]$.

(2). *Tetrahedrite from Wenzel Mine, Wolfach, Baden.*

Rose (*loc. cit.* p. 579). Crystals with barytes and galena on talcose gneiss. Streak, black

Digitized by Google

				Atomic ratios.
Cu	...	25·23	·3997	6
Ag	...	17·71	·1653	
Sb	...	26·68	·2228	2+ ·365
Fe	...	3·72	·0669	1·217
Zn	...	3·10	·0478	
S	...	23·52	·7389 (Calcd. ·7814)	6+1·844
		99·91		

Residual R″ : R‴ : S = 1·217 : ·365 : 1·844
= 6·6 : 2 : 10

corresponding to $6RS.R_2S_3 + \cdot 5RS_2$.

Approx. formula : $[3R_2S.Sb_2S_3] + \frac{1}{5}[6RS.Sb_2S_3]$.

(3). *Tetrahedrite from Dillenburg, Nassau.*

Rose (*loc. cit.* p. 578). Tetrahedral crystals with copper-pyrites. Streak, cherry-red.

				Atomic ratios.
Cu	...	38·42	·6087	6
Ag	...	0·83	·0077	
Sb	...	25·27	·2115	2+ ·355
As	...	2·26	·0304	
Fe	...	1·52	·0278	1·292
Zn	...	6·85	·1055	
S	...	25·03	·7864 (Calcd. ·8038)	6+1·655
		100·18		

Residual R″ : R‴ : S = 1·292 : 355 : 1·655
= 7 : 2 : 9

corresponding to $6RS.R_2S_3 + R''$.

Approx. formula : $[3R_2S.R_2S_3] + \frac{1}{3}[6RS.R_2S_3]$.

(4). *Tetrahedrite from Kapnik, Hungary.*

Rose (*loc. cit.* p. 577). Crystals with quartz, galena, iron-pyrites and blende. Streak, dark red.

Digitized by Google

				Atomic ratios.
Cu	...	37·98	·6017	6
Ag	...	0·62	·0058	
Sb	...	28·94	·2008	2+ ·861
As	...	2·88	·0387	
Fe	...	0·86	·0155	1·262
Zn	...	7·29	·1128	
S	...	25·77	·8096 (Calcd. ·7901)	6+1·996
		99·34		

Residual R'' : R''' : S = 1·262 : ·861 : 1·996
= 6·7 : 2 : 10·7

corresponding to $6RS.R_2S_3 + \cdot 7RS_2$.

Approx. formula: $[3R_2S.R_2S_3] + \frac{1}{5}[6RS.R_2S_3]$.

(5). *Argentiferous Tetrahedrite from Freiberg, Saxony.*

Rose (*loc. cit.* p. 579). Tetrahedral crystals with galena, copper-pyrites, red-silver, blende and quartz. Streak, black.

				Atomic ratios.
Cu	...	14·81	·2346	6
Ag	...	31·29	·2921	
Sb	..	24·68	·2061	2+ ·348
Fe	...	5·98	·1076	1·285
Zn	...	0·99	·0152	
S	...	21·17	·6651 (Calcd. ·6852)	6+1·577
		98·87		

Residual R'' : R''' : S = 1·285 : ·348 : 1·577
= 7 : 2 : 9

corresponding to $6RS.Sb_2S_3 + R''$.

Approx. formula: $[3R_2S.Sb_2S_3] + \frac{1}{6}[6RS.Sb_2S_3]$.

(6). *Tetrahedrite from Clausthal, Harz.*

Schindling (*Neues Jahrb. f. Min.* 1856, 335). Tetrahedral crystals, ...d with copper-pyrites.

Digitized by Google

				Atomic ratios.
Cu	...	33·145	·5251	6
Ag	...	5·135	·0479	
Sb	...	28·520	·2387	2+ ·499
Fe	...	2·730	·0491	1·446
Zn	...	5·775	·0890	
S	...	25·655	·8060 (Calcd. ·7826)	6+2·446
		100·960		

Residual R'' : R''' : S = 1·446 : ·499 : 2·446
= 5·8 : 2 : 9·8

corresponding to $6RS.Sb_2S_3 + \cdot 8S$.

Approx. formula: $[3R_2S.Sb_2S_3] + \frac{1}{2}[6RS.Sb_2S_3]$.

(7). "*Coppite*" *from Val di Frigido, Tuscany.*

Bechi (D'Achiardi *Min. Tosc.* 1873, II, 341, from *Cont. Atti Accad. Georgofili, Florence*, 1868, X, 203). Compact and homogeneous. Sp. gr. 4·718.

				Atomic ratios.
Cu	...	30·10	·4769	6
Sb	...	29·61	·2478	2+1·116
Fe	...	13·08	·2352	2·959
S	...	27·01	·8486 (Calcd. ·8453)	6+4·674
		99·80		

Residual R'' : R''' : S = 2·959 : 1·116 : 4·674
= 5·3 : 2 : 8·4

corresponding to $6FeS.Sb_2S_3 - \cdot 6RS$.

Approx. formula: $[3Cu_2S.Sb_2S_3] + \frac{1}{2}[6FeS.Sb_2S_3]$.

(8). *Mercurial Tetrahedrite from Moschellandsberg, Rhenish Bavaria.*

Oellacher (Sandberger, *Neues Jahrb. f. Min.* 1865, 596). Crystals with copper-pyrites. Streak, black. Sp. gr. 5·095.

Digitized by Google

				Atomic ratios.
Cu	...	32·19	·5100	6
Sb	...	28·45	·1962	
As	...	0·81	·0041	2+ ·446
Bi	...	1·57	·0976	
Fe	...	1·41	·0254	
Zn	...	0·10	·0015	
Hg	...	17·32	·0873	1·390
Co	...	0·23	·0040	
S	...	21·90	·6880 (Calc^{d} ·6819)	6+2·095
Gangue	...	1·39		
		99·87		

Residual R'' : R''' : S = 1·390 : ·446 : 2·095
= 6·2 : 2 : 9

corresponding to $6RS.R_2S_3$.

Approx. formula: $[3Cu_2S.R_2S_3] + \frac{1}{2}[6RS.R_2S_3]$.

(9). *Tetrahedrite from De Soto Mine, Star City, Nevada.*

Burton (*Amer. Journ. Sci.* 1868, XLV, 87). Massive, with blende and pyrites. Sp. gr. 5·00.

				Atomic ratios.
Cu	...	27·40	·4340	6
Ag	...	14·59	·1362	
Sb	...	27·35	·2289	2+ ·408
Fe	...	4·27	·0768	1·183
Zn	...	2·31	·0356	
S	..	24·35	·7650 (Calc^{d} ·7409)	6+2·049
Insol.	...	0·35		
		100·62		

Residual R'' : R''' : S = 1·183 : ·408 : 2·049
= 6 : 2 : 10

corresponding to $6RS.R_2S_3 + S$.

Approx. formula: $[3R_2S.Sb_2S_3] + \frac{1}{3}[6RS.Sb_2S_3]$.

Digitized by Google

(10). "*Julianite*" *from Rudelstadt, Silesia.*

Websky (*Zeits. Deutsch. geol. Ges.* 1871, XXIII, 486). Small cubo-dodecahedra in calcite. Sp. gr. 5·12.

				Atomic ratios.
Cu	...	52·298	·8286	6
Ag	..	0·588	·0050	
Sb	...	1·421	·0118	1·708
As	...	16·782	·2255	
Fe	...	0·787	·0142	·102
S	...	26·503	·8326 (Calcd. ·7870)	5·993
		98·329		

The numbers correspond approximately to $3Cu_2S.As_2S_3$. The correspondence is more exact if, as is most probable from the imperfect method of analysis (fusion with nitre and sodium carbonate), the loss in the analysis is due to loss of arsenic.

This analysis is given as one of the few made on material of comparatively simple composition.

(11). "*Aphthonite*" *from Gärdsjö, Wermland, Sweden.*

Nilson (*Zeits. Kryst. Min.* 1877, I, 417). Massive, with small veins of copper-pyrites. Streak, dark brownish red.

				Atomic ratios.
Cu	...	41·06	·6505	6
Ag	...	6·16	·0575	
Sb	...	26·85	·2247	1·904
Fe	...	0·95	·0171	·152
Zn	...	0·71	·0109	
S	...	23·56	·7402 (Calcd. ·7090)	6·27
		99·29		

The numbers correspond very closely with the formula $3Cu_2S.Sb_2S_3$.

(12). *Fahlerz from Kahl, near Bieber, in Hesse.*

Mutschler (Sandberger, *Neues Jahrb. f. Min.* 1877, 275). Sp. gr. 4·75.

Digitized by Google

				Atomic ratios.
Cu	...	36·8	·5751	6
Ag	...	0·5	·0050	
Sb	...	24·9	·2084	2+ ·516
As	...	2·6	·0349	
Fe	...	3·6	·0648	1·475
Zn	...	4·5	·0693	
Co	...	0·5	·0085	
S	...	25·9	·8137 (Calcd. ·7974)	6+2·415
		98·8		

Residual R'' : R''' : S = 1·475 : ·516 : 2·415
= 5·7 : 2 : 9·3

corresponding to $6RS.R_2S_3$.

Approx. formula: $[3R_2S.R_2S_3] + \frac{1}{4}[6RS.R_2S_3]$.

(13). *Fahlerz from Huallanca, Peru.*

Comstock (*Amer. J. Sci.* 1879, XVII, 401). Large tetrahedral crystals. Sp. gr. 4·7.

				Atomic ratios.
Cu	...	39·09	·6193	6
Ag	...	3·86	·0360	
Sb	...	9·06	·0758	2+ ·354
As	...	13·49	·1812	
Fe	...	5·46	·0982	1·201
Zn	...	2·14	·0330	
S	...	26·74	·8401 (Calcd. ·8453)	6+1·698
		99·84		

Residual R'' : R''' : S = 1·201 : ·354 : 1·698
= 6·7 : 2 : 9·6

corresponding to $6RS.Sb_2S_3 + \cdot 6RS$.

Approx. formula: $[3R_2S.R_2S_3] + \frac{1}{3}[6RS.R_2S_3]$.

(14). *Fahlerz from Kapnik, Hungary.*

Hidegh (*Tsch. Min. Mitth.* 1879, II, 350—8). Crystals with blende. Sp. gr. 4·91 (compare No. 4 above).

Digitized by Google

				Atomic ratios.	
Cu	...	37·88	·5998	6	
Ag	...	1·82	·0128		
Sb	...	24·21	·2026	2+ ·423	
As	...	2·88	·0444		
Fe	...	0·94	·0169	1·262	
Zn	...	7·25	·1117		
S	...	25·81	·7951 (Calcd. ·8049)	6+1·801	
		99·74			

Residual R'' : R''' : S = 1·262 : ·423 : 1·801
= 6 : 2 : 8·5

corresponding to $6RS.R_2S_3$.

Approx. formula: $[3R_2S.R_2S_3] + \frac{1}{3}[6RS.R_2S_3]$.

(15). *Tennantite from Szászka, Hungary.*

Hidegh *(loc. cit.)*. Dodecahedral crystals associated with redruthite. Sp. gr. 4·92.

				Atomic ratios.	
Cu	...	53·60	·8491	6	7
Ag	...	0·08	·0008		
Sb	...	0·10	·0008	1·736	2
As	...	19·11	·2567		
Fe	...	0·39	·0070	·05	
S	...	25·98	·8162 (Calcd. ·8181)	5·76	6·5
		99·26			

Approx. formula: $3Cu_2S.As_2S_3 + \frac{1}{2}Cu_2S$ (redruthite).

(16). *Fahlerz from Herrengrund, Hungary.*

Hidegh *(loc. cit.)* Imperfect crystals, somewhat altered. Sp. gr. 4·77.

Digitized by Google

			Atomic ratios.	
Cu	...	39·81	·6307	6
Ag	...	0·05	·0005	
Sb	...	22·82	·1909	2+ ·421
As	...	4·75	·0638	
Fe	...	4·75	·0854	1·023
Zn	...	1·44	·0222	
S	...	25·75	·8090 (Calcd. ·8052)	6+1·690
		99·87		

Residual R'' : R''' : S = 1·023 : ·421 : 1·690
= 5 : 2 : 8

corresponding to $6RS.R_2S_3 - RS$.

Approx. formula: $[3Cu_2S.R_2S_3] + \frac{1}{3}[6RS.R_2S_3]$.

(17). *Tennantite from Mollie Gibson Mine, Aspen, Colorado.*

Penfield (*Amer. Journ. Sci.* 1892, XLIV, 18). Massive; intermixed with polybasite, from which it only slightly differs in colour. Sp. gr. 4·56.

			Atomic ratios.	
Cu	...	35·72	·5659	6
Ag	...	18·65	·1274	
Sb	...	0·18	·0011	2·007
As	...	17·18	·2308	
Fe	...	0·42	·0075	·985
Zn	...	6·90	·1063	
Pb	...	0·86	·0042	·086
S	...	25·04	·7867 (Calcd. ·8125)	6·808
		99·90		

This analysis is introduced as being one of the very few which agree closely with the 4 : 1 formula, in this case $8Cu_2S.ZnS.Sb_2S_3$. The result of the analysis can only be made to agree with the new 8 : 1 formula, either by supposing the zinc to be present as blende, or, as is more probable from the mode of occurrence of the mineral, by supposing that

Digitized by Google

the material analysed contained admixed polybasite, as shown in the following formula:—

$$9\,[3Cu_2S.As_2S_3] + 2\,[6ZnS.As_2S_3] + [9(Ag,Cu)_2S.As_2S_3].$$
Tennantite. Polybasite.

Taking the atomic proportion of copper and silver in the polybasite to be 1 : 3, as given by Penfield's analysis *(loc. cit.)*, the atomic proportion of these elements in the above formula is about 9 : 2, which is in fairly close agreement with the results of the analysis.

(18). *Fahlerz from Clausthal, Harz.*

Fraatz (W. Hampe, *Chem.-Zeit.* 1893, XVII, p. 1691). Crystals coated with copper-pyrites, but the selected material appeared to be perfectly homogeneous under the microscope. The mean of two closely agreeing analyses is—

			Atomic ratios.	
Cu	...	35·645	·5642	6
Ag	...	3·365	·0314	
Sb	...	28·63	·2394	2 + ·412
Fe	...	2·36	·0422	1·247
Zn	...	5·29	·0815	
S	...	24·72	·7725 (Calc^d. ·7806)	6 + 1·7826
		100·01		

Residual R″ : Sb : S = 1·247 : ·412 : 1·782
= 6 : 2 : 8·65

corresponding to $6RS.Sb_2S_3$.

Approx. formula: $[3R_2S.Sb_2S_3] + \frac{1}{3}\,[6RS.Sb_2S_3]$.

In support of the new formula particular attention may be drawn to the analyses of Rose (Nos. 1-5), to the analysis of "coppite" (No. 7) in which the percentage of iron is as high as 13, and to the analysis of Fraatz (No. 18) which is one of the most recent analyses of tetrahedrite made on pure crystallised material.

Digitized by Google

REVIEW.

The Characters of Crystals, an Introduction to Physical Crystallography. By Alfred J. Moses, E.M., Ph.D., Professor of Mineralogy, Columbia University, New York City. Pp. 211 + VIII. with 321 Text figures. (New York : D. van Nostrand Company, 1899).

Professor Moses has reprinted the series of papers which appeared during the past two years in the *School of Mines Quarterly*, and presents us with an elementary treatise on the physical questions connected with crystals, which will undoubtedly be found most useful by every mineralogical student. In a small compass he gives a very clear sketch of the apparatus and methods used in crystallography without employing any but the simplest mathematics, and thus makes it intelligible to students whose attainments in this subject are not of a high order. In many cases—notably in the chapters dealing with the optical phenomena—the proofs have been omitted altogether, and the reader is referred to other works for fuller and more detailed information.

The book is divided into three parts, dealing respectively with the geometrical, the optical and, finally, the remaining physical characters of crystals. The author follows Groth in avoiding all ideas of hemihedrism, and introduces a simple and effective nomenclature. On this point may we venture to hope that teachers of mineralogy will ere long come to some agreement in the names adopted for the thirty-two classes of symmetry? To explain the phenomena connected with the transmission of light through a crystalline medium, Professor Moses employs Fletcher's geometrical treatment, which avoids all questions as to the properties of the luminiferous aether. In the third part scarcely enough prominence seems to be given to the importance of etching in determining the crystalline symmetry, as exemplified by the researches of Baumhauer and Beckenkamp. In an appendix is added the very complete graduate course in Physical Crystallography given in Columbia University.

The book is well printed on good paper, and enhanced in value by numerous excellent figures.

Digitized by Google

ABSTRACTS.

Chapters on the Mineralogy of Scotland. Chapter VIII, Silicates. (M. F. Heddle, *Trans. Roy. Soc. Edin.* 1899, XXXIX, 841-859.)—Previous "chapters" of this series have been noticed in vols. II, III and IV of this Magazine. The present paper gives a collection of 19 analyses of andalusite, tourmaline, fibrolite, kyanite, epidote, zoisite and idocrase from Scottish localities. Several of these analyses were published in the early volumes of the Magazine in the author's papers on "The County Geognosy and Mineralogy of Scotland." L. J. S.

Baddeleyite from Alnö, Sweden. (E. Hussak, *Neues Jahrb. Min.* 1898, II, 228-9.)—Baddeleyite (ZrO_2), previously only known from Ceylon and Brazil, is now recorded as an accessory constituent in a basic separation from the nepheline-syenite of Alnö, Sweden. This rock, consisting of olivine, magnetite and calcite, corresponds to the basic mother-rock (jacupirangite) of baddeleyite in the nepheline-syenite district of Brazil. From 100 grams of the Swedish rock 0·88 gram of baddeleyite crystals was isolated. They are about 1 – 1½ mm. across, and of a dark chestnut-brown colour; in angles and twinning they agree with the previous descriptions (*Min. Mag.* X, 148; XI, 110), the only difference being in the stronger pleochroism. L. J. S.

Crystals in Blowpipe Beads. (W. Florence, *Neues Jahrb. Min.* 1898, II, 102-146).—A systematic account is given of the results obtained on heating various substances in borax and sodium phosphate beads with or without lead oxide. Numerous figures are given of the crystals characteristic for each element so treated. The method is recommended for the microscopical determination of minerals in the dry way. L. J. S.

Optical Properties of Zoisite (P. Termier, *Bull. Soc. fran. Min.* 1898, XXI, 148-170).—Small crystals of zoisite from a mica-schist at Bobbio in the Cottian Alps have the optic axial plane approximately parallel to $c(001)$, and the acute positive bisectrix nearly normal to $a(100)$; $\rho > v$, $2V = 85° - 40°$, $\alpha = \beta = 1·696$, $\gamma = 1·703$. Analysis gives the usual zoisite formula $HCa_2(Al,Fe)_3Si_3O_{13}$, with $Al : Fe = 9 : 1$; sp. gr. = 3·86. Zoisite from Vanoise in the Savoy Alps has the same optical characters, and both are distinguished as β-zoisite.

Digitized by Google

The zoisite first examined by Des Cloizeaux differs optically from these, and is called *a*-zoisite. Here the acute positive bisectrix has the same position as before, but the optic axial plane is approximately parallel to the perfect cleavage *b*(010); also the dispersion $\rho < v$ is much greater, and sections parallel to *a*(100) do not completely extinguish, but are coloured violet between crossed nicols in white light. Zoisite from Ducktown in Tennessee, North Carolina, San Alpe, and other localities, consists of a regular intergrowth of these two optical varieties, which are identical in chemical composition and crystalline form, being probably anorthic with very nearly rectangular axes. L. J. S.

Chemical Composition of Tourmaline. (S. L. Penfield and H. W. Foote, *Amer. J. Sci.* 1899 [iv], VII, 97-125; and *Zeits. Kryst. Min.* 1899, XXXI, 321).—A detailed historical review is given of the several formulæ which have been proposed for this complex boro-silicate. So many analyses have previously been made that, in order to establish a formula, it was thought best to make two accurate analyses on very carefully selected material of different types. Analysis I is of clear, colourless, glassy, and perfectly pure tourmaline from De Kalb, St. Lawrence Co., New York; sp. gr. > 3·003 < 3·065. Anal. II is of small transparent prisms of a uniform pale green colour from Haddam Neck on the Connecticut River: sp. gr. = 3·089.

	SiO_2.	TiO_2.	B_2O_3.	Al_2O_3.	FeO.	MnO.	MgO.	CaO.	Na_2O.	K_2O.	Li_2O.	H_2O.	F.	Total less O for F.
I,	36·72	0·05	10·81	29·68	0·22	—	14·92	3·49	1·26	0·05	—	2·98	0·93	100·72
II,	36·96	0·03	11·00	39·56	2·14	2·00	0·15	1·28	2·10	—	1·64	3·10	1·13	100·61

These do not give any simple molecular ratios, but by taking the number of hydrogen atoms equivalent to the different metals (*e.g.* Al_2O_3 replaced by 6H) the ratios become, for I, $SiO_2 : B_2O_3 : H = 4 : 1 : 19{\cdot}90$, and for II, $= 4 : 1{\cdot}02 : 19{\cdot}98$. The tourmaline acid is therefore $H_{20}B_2Si_4O_{21}$. Previous analyses are discussed in detail, and made to agree with this formula when the necessary corrections are introduced. For example, in Rammelsberg's thirty analyses the determinations of the silica were probably too high and for the water too low.

The ratio $SiO_2 : (OH,F)$ is not constant, but in all analyses the water when directly determined, is enough for 2(OH), and in only a few cases enough for 3(OH). Further aluminium is always present in sufficient amount to replace more than half the hydrogen atoms. All varieties of tourmaline may therefore be considered as salts of the aluminium boro-silicic acid $H_9Al_3(B.OH)_2Si_4O_{19}$. The remaining 9H may be replaced by

Digitized by Google

aluminium, alkalies, magnesium and iron in varying proportions, and there may also be some basic hydrogen. For example, in the Haddam Neck tourmaline (Anal. II), 6·1H is replaced by Al, 1·1H by R″, 1·2H by R′, whilst 0·6 is basic hydrogen.

When arranged according to the amount of aluminium present, tourmalines fall into the following groups: (1) Lithia tourmaline, with much Al and little Mg and Fe; these are generally light-coloured and transparent, and difficultly fusible, and are found in pegmatite veins. (2) Iron tourmalines. (3) Magnesia-iron tourmalines. The last two varieties are black or dark brown, owing to the presence of iron, and occur in granite, gneiss and schist, though sometimes also in pegmatite veins. (4) Magnesia tourmalines with the least amount of Al; these are light-coloured and easily fusible, and occur in crystalline contact limestones.

These different varieties are the same in crystalline form, and are isomorphous because of the mass effect of the complex radicle $[Al_3(B.OH)_2Si_4O_{19}]$, which is so great that alkalis, R″ and aluminium must be considered as isomorphous constituents, just as sodium (Na_2) and calcium are isomorphous in the complex zeolites and in the sodalite-garnet group, although they are not isomorphous in more simple compounds.

L. J. S.

Sulphur and other minerals from the Malfidano Mine near Buggern, Sardinia. (Dr. F. Miltosevich, *Atti R. Acc. dei Lincei*, V. 249, 1898.)—Some small crystals, rich in faces, were found with anglesite in galena. The forms observed are $a(100)$, $b(010)$, $c(001)$, $m(110)$, $n(011)$, $v(013)$, $e(101)$, $u(103)$, $\phi(305)$, $p(111)$, $\psi(119)$, $w(117)$, $t(115)$, $o(114)$, $s(113)$, $y(112)$, $\delta(221)$, $\gamma(331)$, $\chi(122)$, $q(131)$, $x(133)$, $z(135)$, $\lambda(155)$, $r(811)$, $\alpha(313)$, $\beta(315)$, $\mu(319)$, of which ϕ, λ and μ are new. The most prominent forms are p, s, y, q, β and a The crystals are very similar to those from Saba, East Indies, described by Molengraaff (*Zeits. Kryst. Min.* XIV. 1888, 43). The axial ratios are $a : b : c = 0{\cdot}81368 : 1 : 1{\cdot}90472$, very near those determined by Koksharov.

Together with those of sulphur are numerous crystals of anglesite. The crystals are tabular parallel to (001), and have the forms $a(100)$, $c(001)$, $m(110)$, $n(120)$, $o(011)$, $d(102)$, $z(111)$, $y(122)$. There are also a few thin laminar crystals of barytes, with the forms $c(001)$, $m(110)$, $o(011)$, and $z(111)$. G. F. H. S.

Digitized by Google

Papers on the Symmetry of Crystals, 1888-1898. (J. Beckenkamp.)

The Minerals of the Aragonite Group. (J. Beckenkamp, *Zeits. Kryst. Min.* 1888, XIV, 376-385.)—The minerals aragonite, strontianite, witherite and cerussite are so closely allied in their chemical composition, their geometrical form and physical characters, that they may undoubtedly be considered to have the same arrangement of atoms and molecules. In this paper the author confines himself mainly to crystals of aragonite from Bilin. Except in the case of strontianite from Oberschaffhausen, previously described by him, no trace of hemihedrism has been found in this group. The striations on faces of the form (110) on Bilin crystals indicate that the *c*-axis is polar, which is confirmed by Hankel's investigations on the thermoelectric characters of aragonite. But the most interesting results follow from considering the figures produced by etching sections parallel to (001) with a 20 per cent. solution of HCl for about a minute. The crystals are clearly shown to be composed of different individuals. The Bilin crystals are twinned about (010) as well as about (110). Each individual is hemimorphic with regard to *b* and *c*; *a*, the only axis of symmetry, is polar, and there are no planes of symmetry. This arrangement agrees with the system of striations on the Bilin aragonite and also with the geometrical form of the Oberschaffhausen strontianite, if considered as twinned about (001). The author then explains this type of crystal growth on the hypothesis that during crystallisation heat is emitted which gives rise to electric currents.

1. *Previous observations and deductions therefrom.* (*Zeits. Kryst. Min.* 1890, XVII, 321 330.)—The main conclusions the author draws from his own work and that of other observers (chiefly Hankel[1] and Lehmann[2]) are as follows:—

(*a*) The anomalies found in crystals of barytes and strontianite can only be explained by regarding the crystals as composed of individuals of very low symmetry.

(*b*) There is no important difference between crystals with an apparently symmetrical electrical axis and those with a one-sided axis.

(*c*) The electrical stresses arising during the growth of a crystal have a most important influence on the arrangement of the molecules.

---

[1] *Elektrische Untersuchungen*, 9te Abhandlung, 1872. [2] *Molekularphysik*, 1889.

Digitized by Google

(*d*) Holohedral and holomorphic crystals are impossible, and can only owe their apparent existence to twinning.

2. *Gypsum from Zimmersheim in Upper Alsace.* (*Ibid.* 1890, XVII, 331-335.)—Imbedded in fibrous gypsum were found crystals of the same mineral, varying in length up to 10 mm. Microscopic investigation showed that the direction of the fibres always coincided with the *c* prism edge. The crystals display striation-zones, the direction of which coincides with that of the fibres. These striations might be supposed to be due to the pressure of the fibres on the completed crystals; but, since the angles between the faces show no greater variation than is found in the case of crystals which have grown freely, and, moreover, since there is no trace of further disturbance, the author thinks it more probable that these striations arose during the growth of the crystals. Three crystals were measured, and the position of the striation-zone determined in each case. The forms present are (010), (11$\bar{1}$), (111) and (110). The pyramid faces which lie nearest to the striation-zone are invariably the largest. The striation-zones have never quite the same crystallographic orientation. The author finally concludes that the mutual attractions of the molecules is independent of the surrounding conditions, but dependent on the direction in the crystal, and also that a crystal face has at least two directions of maximum attraction.

3. *Aragonite from Bilin.* (*Ibid.* 1891, XIX, 242-264, and 1892, XX, 161-163.)—A careful examination was made of the vicinal faces, and their positions determined as accurately as possible. The axial ratios calculated from the angles between faces of the form (121) are $a:b:c=0{\cdot}62280:1:0{\cdot}72036$. The symmetry derived from the vicinal faces was not in accordance with that derived from a study of the etched figures (see above, *The Minerals of the Aragonite Group*). Further experiments, especially those of von Ebner, in which formic acid was the agent employed, show that the symmetry is the same in both cases. The author finally concludes that the three axes are enantiopolar directions, and the principal planes are planes of twinning; also the simple crystal has rhombic ogdohedral symmetry. The author accounts for the vicinal faces on the theory that the electrical attraction is tangential and not normal to a crystal face, as has been generally supposed.

4. *Calcite from Nieder-Rabenstein.* (*Ibid.* 1892, XX, 163-167.)—The crystals observed are of two types: scalenohedral and prismatic. The most prominent form on crystals of the first type is 20$\bar{1}$. It usually has smooth faces. The ends are terminated by (610), which is striated

Digitized by Google

parallel to its acute edge, and also by (110). The majority of the crystals are traversed by lamellæ twinned about (110), which gives them a monosymmetric character. Should the distance between alternate layers be the molecular thickness, then these crystals must both geometrically and physically belong to the monosymmetric system. The crystals of the second type are distinguished by the predominance of the prism of the first order, or a form very near it. There also appear $(3\bar{1}\bar{1})$ and $(11\bar{1})$ and sometimes a form near $[35\cdot\bar{1}9\cdot\bar{1}8]$. From striations and the difference of the sizes to which faces of the form $(20\bar{1})$ have developed, the author concludes that crystals of this type have tetartohedral-hemimorphic or ogdohedral symmetry. Since Kobell and Tschermak have shown that dolomite belongs to this type of symmetry, the question arises whether the crystals are not really dolomite. But chemical, geometrical and physical tests showed clearly that they are calcite.

5. *Barytes.* (*Ibid.* 1897, XXVII, 583-585; 1897, XXVIII, 69-102; 1897, XXX, 55-65.)—Hemimorphic crystals have been described previously by the author and others. He here describes twins about (2.1.128) and (0.800.1). Barytes cannot then belong to the holohedral rhombic class of symmetry.

In the second paper the vicinal faces and pyroelectrical and etching experiments are described and discussed at length. The axial ratios calculated from the angles $(110):(1\bar{1}0)$ and $(011):(01\bar{1})$ are $a:b:c=0\cdot8146:1:1\cdot8119$. Two kinds of habit were noticed: crystals elongated in the direction of the macro- or brachy-diagonal. The symmetry of both is the same. A completely developed crystal of barytes is composed of eight individuals symmetrically disposed with respect to the three pinacoids. The molecule must have electrical polarity, on which depends the growth of the crystal and also its decay when acted on by solvents. The author then gives a mechanical explanation of pyroelectrical phenomena in barytes. In the third paper he discusses the possible molecular arrangement, and concludes that it must consist of a double network of similar molecules, the corner of each network being at the centre of the other.

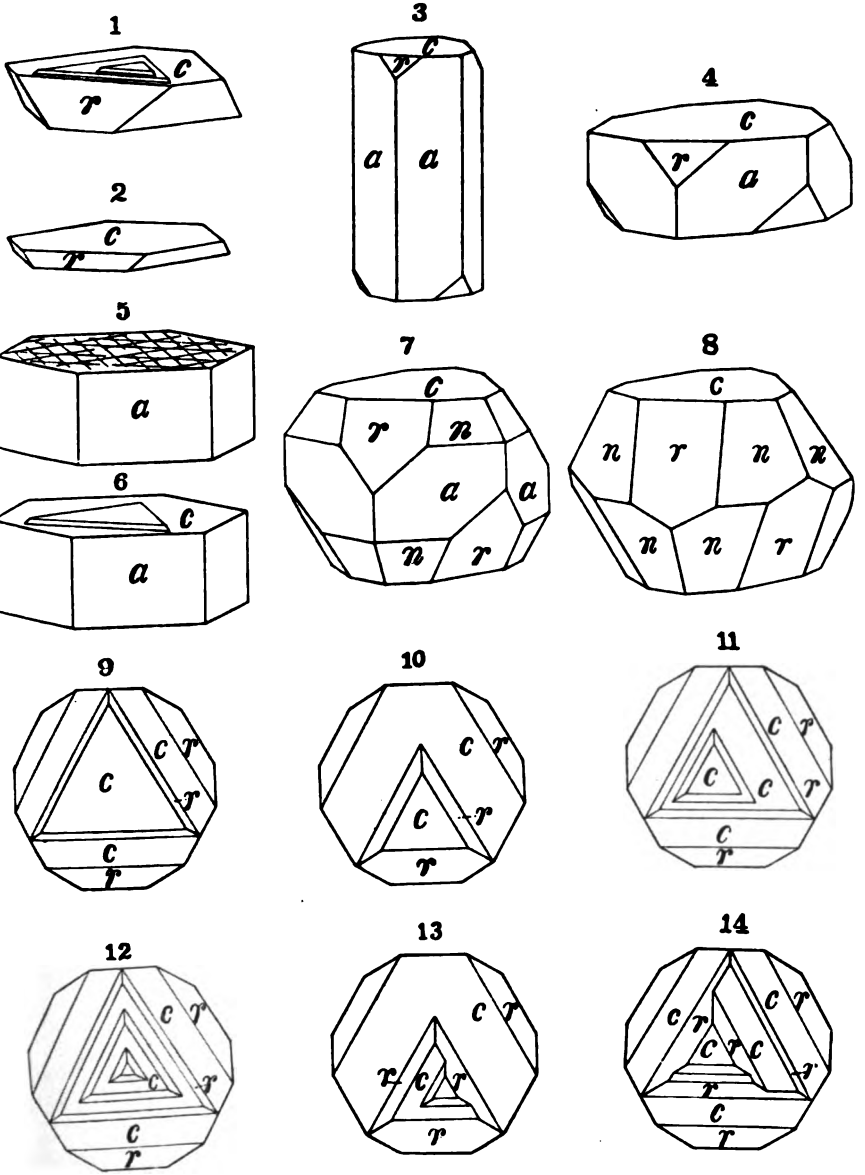
6. *Twins with inclined axes.* (*Ibid.* 1898, XXX, 321-325.)—Each molecule may be supposed to have three circular currents flowing round it in planes mutually perpendicular. Equilibrium will be established when corresponding planes of adjacent molecules are parallel, and also when they are inclined. The author uses this theory to explain the twinning and growth of aragonite and tridymite.

Digitized by Google

7. *The Rotation of the Plane of Polarisation.* (*Ibid.* 1898, XXX, 325-345; Cf. *Ann. Phys. Chem.* 1899, LXVII, 474-480.)—A short critical account of the history of the subject is first given, and the statical theories of Mallard and Sohncke studied in detail. These depend on an arrangement of monoclinic or triclinic sections similar to that of mica in Reusch's experiment. They fail, however, to account for the fact that equally thick plates of optically active crystals of the cubic system have the property of rotating the plane of polarisation an equal amount independently of the orientation in the crystal. Using the structural arrangement for quartz and tridymite given in the preceding paper, the author shows how the optical activity and inactivity may be explained in the two cases. Further, he shows that in the case of a cubic or octahedral network the rotation depends on the thickness of the plate, and not on its orientation in the crystal. G. F. H. S.

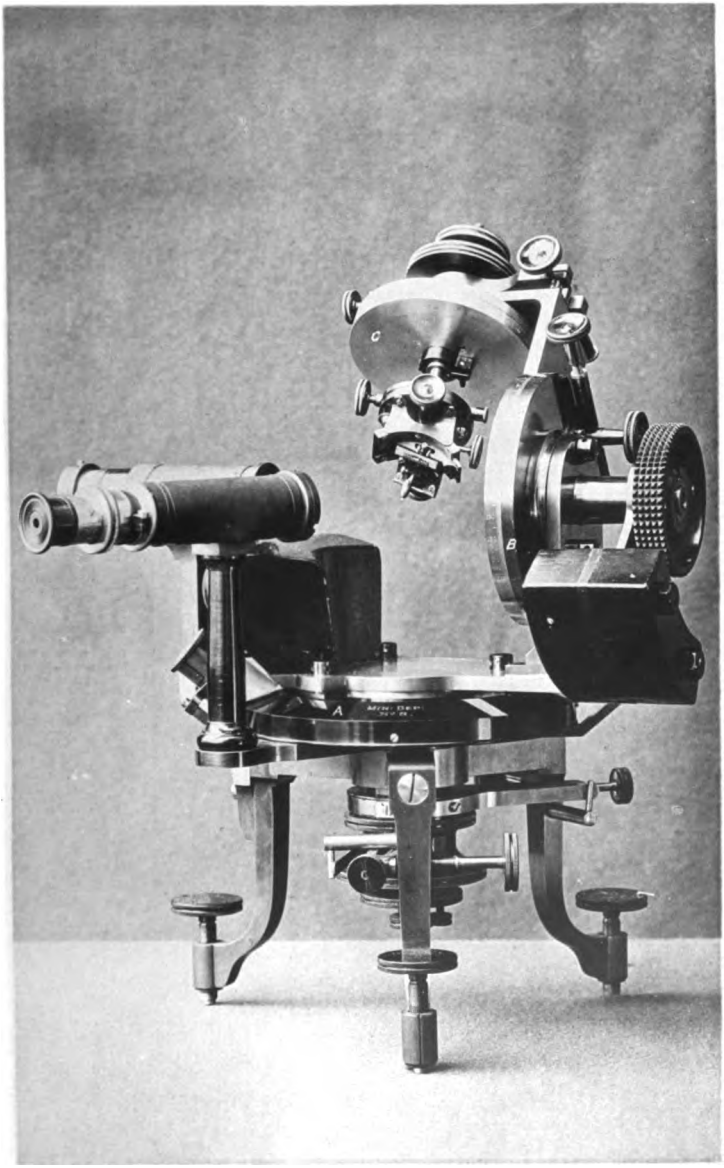
Digitized by Google

Digitized by Google



Digitized by Google

Digitized by Google



Collo by Morgan & Kidd, Richmond, S.W.

Digitized by Google

Digitized by Google

THE MINERALOGICAL MAGAZINE

AND

JOURNAL

OF THE

MINERALOGICAL SOCIETY.

No. 57. JULY, 1900. Vol. XII.

Communications from the Oxford Mineralogical Laboratory.

On the constitution of the natural Arsenates and Phosphates.

By E. G. J. Hartley, B.A.

[Read June 20th, 1899.]

Part III.—*Plumbogummite and Hitchcockite.*

THE present paper deals with the somewhat obscure lead aluminium phosphates, of which the following varieties have hitherto been described :—

(i) The original plumbogummite, a mineral found at Huelgoat in Brittany, and at Nuissière, Dept. Rhône.

(ii) Some varieties of pyromorphite, containing alumina and water as constituents. These pyromorphites occur also at Huelgoat, and are usually quoted in books on Mineralogy as plumbogummite, although Damour, in his original paper on the subject, clearly distinguishes between the true plumbogummite and the aluminous pyromorphites.

(iii) The American mineral, hitchcockite, occurring in the Canton Mines, Georgia.

(iv) A Cumberland mineral, which for some time was mistaken for zinc silicate, but has recently been shown to be a phosphate of lead and aluminium (Miers, *Min. Mag.* 1896, XI, 272).

Digitized by Google

The want of agreement in the old analyses of plumbogummite, and the possibility of finding some relationship between it and the Cumberland mineral, of which no quantitative results have been published, made it desirable both to repeat the analysis of the former and to make for the first time a complete analysis of the latter.

Finally, a further examination of the American mineral was undertaken, in order to complete the revision of these phosphates.

The present paper is divided into four parts:—

(*a*) A history of previous work.

(*b*) A short account of the analytical methods adopted.

(*c*) The results of the present investigation.

(*d*) Theoretical considerations as to the constitution of the several minerals.

(*a*) *History.*

Plumbogummite was described by Romé de Lisle in 1779 (*Cristallographie*, 1783, III, 399). The first published analysis is by Berzelius (*Ann. des Mines*, 1820 [1], V, 245), and was made on a specimen from Huelgoat. He obtained the following numbers:—

PbO	40·14
Al_2O_3	37·00
H_2O	18·80
SO_3	·20
CaO,MnO,Fe_2O_3... ...	1·80
SiO_2	·60
	98·54

In this analysis phosphoric acid was entirely overlooked, and, as stated by Damour, it was doubtless weighed with the alumina.

In 1835 Dufrénoy published an analysis of plumbogummite from Nuissière, Dept. Rhône (*Ann. des Mines*, 1835 [3], VIII, 243). He regarded the phosphoric acid as an impurity, and appears not to have taken sufficient care to separate it from alumina. His results were:—

SiO_2	2·11
Al_2O_3	34·23
PbO	43·42
P_2O_5	1·89
H_2O	16·14
Loss	2·21
	100·00

Digitized by Google

In 1840 Damour (*Ann. des Mines*, 1840 [3], XVII, 191) gave a further analysis of plumbogummite from Huelgoat, and also of two pyromorphites from the same locality containing aluminium hydrate.

These analyses were as follows:—

	Plumbogummite.	Aluminiferous pyromorphites. (1)	(2)
$PbCl_2$ ...	2·27 ...	8·24 ...	9·18
P_2O_5 ...	8·06 ...	12·05 ...	15·18
PbO ...	85·10 ...	62·15 ...	70·85
CaO ...	·80 ...	— ...	—
Al_2O_3 ...	34·32 ...	11·05 ...	2·88
H_2O ...	18·70 ...	6·18 ...	1·24
Fe_2O_3 ...	·20 ...	— ...	—
SO_3 ...	·30 ...	·20 ...	·40
	99·75	99·92	99·73

From these results Damour suggests that plumbogummite is nothing more than a pyromorphite containing a large quantity of aluminium hydrate.

He criticises Dufrénoy's paper, pointing out that he has in all probability overlooked the greater part of the phosphoric acid.

It seems possible, however, that Damour's method of separating alumina from phosphoric acid was not altogether satisfactory. He fused the mineral with sodium carbonate and nitre, dissolved the mass in water, and after removing any lead remaining in solution by ammonium sulphide, he heated the liquid to boiling, and gradually added excess of pure silica, which, he said, precipitates all the alumina, leaving the phosphoric acid in solution. The separation of these substances by means of ammonium molybdate is probably much more exact.

No analysis of the plumbogummite from Huelgoat or Nuissière has been published since this date.

Hitchcockite has only been described hitherto as occurring in one locality, the Canton Mines, Georgia.

It was first mentioned by Shepard in 1856 (*Rep. Canton Min. Ga.*, 1856). He gave no analysis, but stated that it lost 27 per cent. on ignition. In 1857 Genth (*Am. J. Sci.* 1857, xxiii, 424) published the following analysis of hitchcockite:—

Digitized by Google

PbO	29·04	per cent.
Al_2O_3	25·54	,,
P_2O_5	18·74	,,
H_2O	20·86	,,
Fe_2O_3	·90	,,
CaO	1·44	,,
CO_2	1·98	,,
Cl	·04	,,
Insoluble Residue ...	·48	,,
	99·02	

These numbers agree fairly well with the formula $PbO.2Al_2O_3.P_2O_5.9H_2O$, for which the percentage composition is:—

P_2O_5	19·4
Al_2O_3	27·9
PbO	30·5
H_2O	22·2
	100·0

(*b*) *Analytical Methods.*

The constituents to be determined in these minerals were lead oxide, alumina, phosphoric acid, carbonic acid and water in all cases, while chlorine and a small quantity of sulphuric acid were found in addition in plumbogummite and an accompanying aluminiferous pyromorphite.

The water and carbonic acid were determined by heating to redness a portion of the mineral in a hard glass tube in a current of dry air free from CO_2, and weighing the products in a calcium chloride tube and potash bulbs respectively. The lead was either estimated by precipitation as sulphide from a dilute hydrochloric acid solution, in which case it was re-dissolved, precipitated as carbonate and weighed as oxide, or it was in some cases separated and weighed as sulphate. The alumina in the filtrate from the lead was precipitated with ammonia after separating the phosphoric acid by means of metallic tin in a strong nitric acid solution (Girard's method). The phosphate of tin was dissolved in ammonium sulphide, and the phosphoric acid precipitated by magnesia mixture. This method was not altogether satisfactory, and it was found better to precipitate the alumina and phosphoric acid together with ammonia and weigh them, subsequently deducting the weight of phosphoric acid as found by the [illegible] method in a separate portion. In the case of the aluminiferous

Digitized by Google

pyromorphite, where the phosphoric acid was in large excess of the alumina, the precipitate formed when ammonia was added to the filtrate from lead sulphide was weighed and calculated as $AlPO_4$, the residual phosphoric acid in the filtrate being then thrown down by magnesia mixture.

With regard to the estimation of chlorine, it was found best to dissolve the mineral in dilute nitric acid under pressure in a sealed tube, as it was only soluble in the ordinary way by boiling for a long time with strong nitric acid, in which process there might be a considerable loss of chlorine.

(*c*) *Results of the present investigation.*

(i) The Cumberland mineral.

This mineral occurs apparently only at the old Roughten Gill lead mines, which were worked about thirty years ago in the neighbourhood of Caldbeck, Cumberland.

It varies in colour from a very faint lavender to a beautiful bright smalt blue, and occurs sometimes as a thin crust overlying vein quartz, and sometimes intimately mixed with minute quartz crystals, and constituting the main mass of the vein stuff. The colour is probably due to a small amount of copper which it contains, though in too small a quantity to estimate satisfactorily. It is difficult to separate mechanically the phosphate mineral from intermixed quartz, but since it is readily soluble in strong hydrochloric acid, a chemical separation was easily effected.

The specimen taken for analysis contained about ten per cent. of quartz, but so far as could be seen no other impurity, being quite transparent and free from inclusions. The quartz is visible under the microscope.

The specific gravity was not ascertained owing to the great difficulty in separating sufficient material in an absolutely pure condition.

The following is the result of the analysis:—

·2022 of a gram gave		·0263 H_2O	=13·01	per cent.	H_2O
·2022	,, ,,	·0064 CO_2	= 3·16	,,	CO_2
·3188	,, ,,	·0388 H_2O	=12·44	,,	H_2O
·3188	,, ,,	·0096 CO_2	= 3·08	,,	CO_2
·3188	,, ,,	·1561 $PbSO_4$	=36·84	,,	PbO
·3041	,, ,,	·1132 PbO	=37·23	,,	PbO
·3041	,, ,,	·0874 Al_2O_3	=28·74	,,	Al_2O_3
·3041	,, ,,	·0892 $Mg_2P_2O_7$	=18·76	,,	P_2O_5
·2896	,, ,,	·0694 $Mg_2P_2O_7$	=18·52	,,	P_2O_5

Digitized by Google

		I.	II.	III.	IV.	Mean.
H_2O	...	13·01	12·44	—	—	12·73
CO_2	...	3·16	3·08	—	—	3·12
PbO	...	—	36·84	37·23	—	37·03
Al_2O_3	...	—	—	28·74	—	28·74
P_2O_5	...	—	—	18·76	18·52	18·64
						100·26

Traces of copper and arsenic acid were also present. No water was lost by the mineral in dried air or at 100°C.

(ii) Hitchcockite, from Canton Mine, Georgia.

The specimens of this mineral taken for analysis consisted of a very thin whitish crust coating a granular mixture of galena and quartz, with some iron and copper pyrites. It was not found possible to obtain this in as pure a condition for analysis as the previous mineral, and the quantities available were very small. The crystalline material was picked out as carefully as possible under a microscope, but it contained some exceedingly minute black inclusions, which could not be completely removed. The numbers obtained on analysis were as follows:—

·2375	of a gram	gave	·0816	PbO ...	=34·36	per cent.	PbO
·2375	,,	,,	·0700	Al_2O_3 ...	=29·48	,,	Al_2O_3
·3030	,,	,,	·0084	CO_2 ...	= 2·77	,,	CO_2
·3030	,,	,,	·0446	H_2O ...	=14·71	,,	H_2O
·3030	,,	,,	·0025	Insoluble Residue	= ·82	,,	Residue
·3030	,,	,,	·0833	$Mg_2P_2O_7$ ...	=17·58	,,	P_2O_5
					99·72		

(iii) Plumbogummite, from Huelgoat.

The specimen of plumbogummite examined consisted evidently of two sorts of material, one being a dark-brown gum-like substance, transparent, and showing a crystalline structure under the microscope. The second mineral was much lighter coloured, and occurred mostly as a crystalline crust, but some minute crystals of this material, situated in a small cavity, were examined by Professor Miers, and proved to be hexagonal, with angles near those of pyromorphite. Unfortunately these did not occur in sufficient quantity even for a qualitative analysis. Of the two minerals, the first agrees completely in appearance with the published description of the original plumbogummite. In the course of analysis it was found to contain some organic matter, since on

Digitized by Google

heating it turned black and smelt like charred paper. Unfortunately this was not discovered till the last portion was being used for the estimation of carbonic acid and water by the method given above, so that it was impossible to distinguish accurately between the percentage of carbonic acid and water, present as such in the mineral, and the percentage which was due to the oxidation of the organic carbon and hydrogen. So far as could be judged, however, by the difference between the loss of weight of the mineral on heating and the gain of weight of the absorption tubes, the organic matter must have amounted to about one per cent.

The analytical results were as follows:—

(*a*) The dark mineral.

I.

·3540 of a gram gave	...	·0042 AgCl	= ·29 per cent.	Cl
·3641	,,	,,	...	·0528 H_2O	=14·50	,,	H_2O
·3641	,,	,,	...	·0167 CO_2	= 4·59	,,	CO_2
·3641	,,	,,	...	·1046 $Mg_2P_2O_7$	=18·37	,,	P_2C_5
·3980	,,	,,	...	·1721 PbO	=43·24	,,	PbO
·3980	,,	,,	...	·0758 Al_2O_3	=19·04	,,	Al_2O_3
·3797	,,	lost at 100° C.	·0195 H_2O	= [5·13]	,,	H_2O
				100·03		

II.

·4415 of a gram gave	...	·0123 $BaSO_4$	= ·96 per cent.	SO_3
·4415	,,	,,	...	·0028 AgCl	= ·16	,,	Cl
·4415	,,	,,	...	·1321 $Mg_2P_2O_7$	=19·14	,,	P_2O_5
·4332	,,	lost at 100° C.	·0208 H_2O	= 4·80	,,	H_2O
·4332	,,	gave on ignition	·0461 H_2O	=10·64	,,	H_2O
·4332	,,	,,	,,	·0202 CO_2	= 4·66	,,	CO_2
·4332	,,	,,	...	·2290 $PbSO_4$	=38·91	,,	PbO
·4332	,,	,,	...	·0909 Al_2O_3	=20·98	,,	Al_2O_3
				100·25		

The percentages in both analyses should doubtless amount to a somewhat higher total, since some of the CO_2 and H_2O is derived from carbon and hydrogen in a lower state of oxidation.

The interpretation of these analyses will be discussed below.

Digitized by Google

(*b*) The light coloured mineral.

·5621 of a gram gave		·0025 CO_2	=	·44	per cent.	CO_2
.5621	,, ,,	·0110 H_2O	=	1·96	,,	H_2O
·3436	,, ,,	·0322 AgCl	=	2·32	,,	Cl
·3436	,, ,,	·2609 PbO	=	75·93	,,	PbO
·3436	,, ,,	·0228 $AlPO_4$	=	2·76	,,	Al_2O_3
				3·86	,,	P_2O_5 } 17·02
·3436	,, ,,	·0707 $Mg_2P_2O_7$	=	13·16	,,	P_2O_5 }
·4144	,, ,,	·0278 $AlPO_4$	=	2·80	,,	Al_2O_3
				3·90	,,	P_2O_5 } 16·60
·4144	,, ,,	·0823 $Mg_2P_2O_7$	=	12·70	,,	P_2O_5 }

Calculating the chlorine as lead chloride, and taking the mean of the alumina and phosphoric acid determinations, the numbers are as follows :

CO_2	...	...	...	·44 per cent.
H_2O	...	...	...	1·96 ,,
$PbCl_2$	...	...	...	9·11 ,,
PbO	...	...	...	68·62 ,,
Al_2O_3	...	...	...	2·78 ,,
P_2O_5	...	...	...	16·81 ,,
				99·72

(*d*) *Theoretical considerations as to the constitution of the minerals analysed above.*

The analyses of the Cumberland mineral and the American hitchcockite agree sufficiently well to make it more than probable that these two are identical, and their constitution is expressed by a simple formula, viz.—$2PbCO_3.Pb_3(PO_4)_2 + 6\,[AlPO_4.2Al(OH)_3.H_2O]$, or—

$$5PbO.9Al_2O_3.4P_2O_5.2CO_2.24H_2O.$$

Comparing this formula with the numbers obtained, we get the following table :—

	Calculated.	Cumberland Mineral.	Hitchcockite.
PbO ...	35·73	... 37·03	... 34·36
Al_2O_3 ...	29·41	... 28·74	... 29·47
P_2O_5 ...	18·20	... 18·64	... 17·58
CO_2 ...	2·82	... 3·12	... 2·77
H_2O ...	13·84	... 12·73	... 14·71
	100·00	100·26	98·89

Digitized by Google

The above analysis of hitchcockite, however, differs considerably from Genth's. Genth found only about 29 per cent. of lead oxide, whereas the present specimen contained 34 per cent. Again, the percentage of water in Genth's mineral was nearly 21 per cent. as compared with 14·7.

This difference may, in the case of the lead, be due to the replacement of lead oxide by lime. The percentage of lime in his analysis was 1·44, which, if calculated into its equivalent of lead oxide, amounts to 5·73 PbO. When this latter number is added to the 29·04 per cent. PbO, it gives a total of 34·77, which approaches the calculated percentage.

With regard to the water, it is just possible that Genth may have estimated it by loss of weight of the mineral on ignition without taking into account the simultaneous loss of carbonic acid. Unfortunately the exact details of the analysis are not given in the published description.

The close resemblance in composition of the Cumberland and American minerals may however be put forward as a point in favour of the correctness of the present analysis of the latter.

In discussing the question of the constitution of plumbogummite, it will be well to compare the present analysis with those previously published.

It will be noticed, firstly, that carbonic acid was entirely overlooked by all previous analysts, and as the percentage of water was in most cases estimated by loss of weight on heating the mineral, the carbonic acid was doubtless included in the number given for water. Dufrénoy, however, determined the water by collecting it in a calcium chloride tube, and he observed that there was a greater loss of weight of the mineral than gain of weight of the absorption tube, and in fact he includes this loss in his published analysis as amounting to 2·21 per cent.

Secondly, the want of agreement in the determinations of alumina and phosphoric acid is very evident, but it seems certain that this was due to inadequate methods of separating these constituents.

Berzelius, indeed, did not observe the presence of phosphoric acid at all. Dufrénoy found only a small quantity, while Damour, who was the first to regard it as an essential constituent of plumbogummite, made use of a method of separation which, as was pointed out above, was probably unsatisfactory.

If, however, the numbers, showing the percentages of (i) lead oxide, (ii) alumina and phosphoric acid, and (iii) water and carbonic acid, are compared, it will be seen that the differences are not great, and such differences as occur in the case of the lead oxide are doubtless due, as in

Digitized by Google

the two present analyses, to varying proportions of pyromorphite present in this mineral.

	Berzelius.	Dufrénoy.	Damour.	Hartley.	
				(i)	(ii)
PbO ...	40·14	43·42	36·92	43·24	38·91
$Al_2O_3+P_2O_5$	37·00	36·12	42·32	37·41	40·02
H_2O+CO_2	18·80	18·35	18·70	19·09	20·10

In considering the question of the constitution of plumbogummite, it seemed possible that this substance might be a mixture of pyromorphite and hitchcockite, together with some water held more loosely than in the latter mineral, and a small quantity of organic matter and lead sulphate.

In order to test this view, a calculation was made in which the proportion of pyromorphite corresponding to the chlorine, the water lost at 100° C., and lead sulphate corresponding to the SO_3, were deducted from the total percentages, and the remainder was brought to 100 parts.

The numbers so obtained were as follows :—

	Analysis I.	Analysis II.	Calculated for hitchcockite.
H_2O ...	11·55[1] ...	12·42[1] ...	18·84
CO_2 ...	5·66[1] ...	5·44[1] ...	2·82
PbO ...	38·80 ...	36·43 ...	35·73
Al_2O_3 ...	23·48 ...	24·49 ...	29·41
P_2O_5 ...	20·51 ...	21·22 ...	18·21

The agreement is certainly not good, the ratio of phosphoric acid to alumina being very different.

In favour, however, of this view, it must be remembered that the mineral was not a well-crystallised substance, so that it would not be surprising to find one or more of the constituents out of proportion.

At all events, the above view seems more reasonable than Damour's suggestion, that the mineral is a mixture of aluminium hydrate with pyromorphite.

Much the same view can also be taken of the light-coloured mineral. This latter is clearly pyromorphite in the main, as will be seen by comparing its composition with that of pyromorphite.

---

[1] Partly derived from organic matter.

Digitized by Google

	Light-coloured plumbogummite.		Pyromorphite.
$PbCl_2$... ...	9·11	... ...	10·26
PbO	68·62	... ...	74·03
P_2O_5	16·81	... ...	15·71
Al_2O_3 ...	2·78		
CO_2	·44		
H_2O	1·96		

Deducting pyromorphite from the former mineral, as calculated from the chlorine, the following constituents are left:—

H_2O	1·96
CO_2	·44
PbO	3·08
Al_2O_3...	2·78
P_2O_5	2·91

Here, of course, all the errors of analysis fall on this small residue, so that the numbers cannot be expected to agree very closely; but they are sufficient to prove that, at all events, there is more oxide of lead and phosphoric acid than is required for a simple mixture of pyromorphite and aluminium hydrate.

If Damour's two analyses of so-called aluminiferous pyromorphites are treated in the same way, in both cases some oxide of lead is left over and above that required for pyromorphite and lead sulphate; but in the first analysis it is only a very small proportion, and there is no excess of phosphoric acid—in fact, there is less than that required for pyromorphite as calculated from the chlorine. In the second example, perhaps by chance, the residue agrees very fairly well with the proportions in hitchcockite. The numbers so obtained are:—

	(i)		(ii)
PbO ...	2·18	...	3·51
Al_2O_3 ...	11·05	...	2·88
H_2O ...	6·1	...	1·24
P_2O_5 ...	—	...	1·12

Taking into consideration the fact that these minerals are by no means well-crystallised substances, it seems reasonable to suggest that they may be somewhat impure mixtures of pyromorphite with hitchcockite, and to ascribe to the latter mineral the formula given above, namely:—

$$2PbCO_3.Pb_3(PO_4)_2+6[AlPO_4.2Al(OH)_3.H_2O].$$

Digitized by Google

Communications from the Oxford Mineralogical Laboratory.

On the constitution of the natural Arsenates and Phosphates.

By E. G. J. Hartley, B.A.

[Read Jan. 23rd, 1900.]

Part IV.—*Beudantite.*

THE constitution of beudantite, which is one of the small group of double sulphates with phosphates or arsenates, has so far not been satisfactorily determined. As will be seen below, the results obtained by several analysts differ so much that it is impossible to deduce any simple formula from them.

Since these differences appear to have arisen mainly from the great difficulty in obtaining the mineral in a pure condition, it has seemed desirable to make a fresh analysis on very carefully purified material, in order to obtain satisfactory evidence as to its true composition.

It is proposed in this paper to give, firstly, a short history of previous work on the subject; secondly, some account of the analytical methods adopted in the present research; thirdly, a description of the specimen of beudantite taken for analysis, and the results obtained, together with some suggestions as to the true composition of this mineral.

(*a*) *History.*

In 1826 Lévy (*Ann. de Phil.* 1826, II, 195) first described beudantite as occurring at Horhausen. With regard to its chemical properties he only mentioned that it contained oxide of lead and oxide of iron, according to Wollaston. Damour (*Ann. Chim. Phys.* 1844, 3 Series, X, p. 73) considered it to be hydrated arsenate of iron (pharmacosiderite), containing some oxide of lead as an impurity.

Percy (*Phil. Mag.* 1850, XXXVII, p. 161) published two analyses of some of Lévy's original specimen from Horhausen. He states that the material in the first of these analyses was decidedly impure, while that used in the second was purified as far as possible with the help of a ·eroscope, but was still not quite free from inclusions.

Digitized by Google

His results were:

	I.	II.
PbO ...	24·47	29·52
Fe_2O_3	42·46	37·65
SO_3 ...	12·31	12·35
As_2O_5	9·68	18·60
P_2O_5 ...	1·46	undet.
H_2O ...	8·49	8·49
	98·87	101·61

Percy did not suggest any formula for beudantite from these numbers.

Sandberger (*Pogg. Ann.* 1857, C, 611) described a new variety of beudantite from Dernbach, which contained phosphoric acid in the place of arsenic acid. He quoted analyses by Müller both of this new variety and also of the Horhausen mineral. Müller obtained the following numbers:

	Dernbach.	Horhausen.	Calculated for $PbSO_4.Pb_3(PO_4)_2.3FePO_4.24H_2O$
PbO ...	26·92	23·43	26·09
Fe_2O_3 ...	44·11	47·28	42·10
SO_3 ...	4·61	1·70	2·34
As_2O_5 ...	trace	12·51	—
P_2O_5 ...	13·22	2·79	16·83
H_2O ...	11·44	[12·29]	12·62
	100·30	100·00	99·98

In the same year Rammelsberg (*Pogg. Ann.* 1857, C, 581) published an analysis of a specimen of beudantite which had been discovered in the previous year at "Glendone," Co. Cork, by Krantz. He stated that it was only with difficulty soluble in strong hydrochloric acid, in which respect it differed from the Horhausen and Dernbach varieties, both of which, according to Percy and Sandberger, are readily attacked by this solvent. His numbers were:—

		Calculated for $4Fe_2O_3.2PbO.3SO_3.P_2O_5.9H_2O$
PbO ...	24·05	27·37
Fe_2O_3 ...	40·69	39·26
CuO ...	2·45	—
P_2O_5 ...	8·97	8·71
As_2O_5 ...	·24	—
SO_3 ...	13·76	14·72
H_2O ...	9·77	9·94
	99·93	100·00

Digitized by Google

(*b*) *Analytical Methods.*

The constituents to be determined in this case were oxides of lead, copper and iron, phosphoric and sulphuric acids, a trace of arsenic acid and water of crystallisation. For the estimation of the metals a portion of the mineral was dissolved in strong hydrochloric acid, and evaporated with a little sulphuric acid till the whole of the hydrochloric acid was driven off. The lead was then weighed as sulphate. In the filtrate the copper and arsenic were precipitated as sulphides, and the arsenic was separated from the copper by sodium sulphide, the copper being ignited and weighed as oxide. The arsenic was re-precipitated as sulphide and oxidised with fuming nitric acid to arsenic acid; the liquid was evaporated to a small bulk and precipitated with magnesia mixture. The precipitate was, however, too small to be weighed. The filtrate from the copper and arsenic was boiled till all the sulphuretted hydrogen was driven off. The iron was then oxidised with nitric acid, neutralised with ammonium carbonate, and precipitated together with the phosphoric acid by ammonium acetate, the two being weighed together. The phosphoric acid was determined in a separate portion, which was also used for the sulphuric acid estimation. This portion was dissolved in hydrochloric acid, and the chlorides were converted into nitrates by repeated evaporation with nitric acid. A few drops of lead nitrate were added to the liquid, which was evaporated nearly to dryness, and the residue was taken up with water and a little alcohol, the precipitate of lead sulphate being then collected and weighed. The filtrate was evaporated to dryness to remove alcohol, the residue taken up with dilute nitric acid, and the phosphoric acid was estimated by the molybdate method and weighed as magnesium pyrophosphate.

With regard to the water, preliminary experiments showed that none was lost either in a current of dry air or at 100° C.

The total water was therefore determined by heating a portion of the mineral, weighed into a porcelain boat, in a hard glass tube connected with a weighed calcium chloride tube, a current of dry air being slowly drawn through the apparatus. In order to prevent any arsenic or sulphur trioxide from passing over into the absorption tube, a heated layer of a mixture of litharge and lead dioxide was interposed between the latter and the boat.

(*c*) *Description of specimen and results of analysis.*

The specimen analysed belonged to the Oxford University Collection, and was obtained by exchange from the British Museum. It was

Digitized by Google

acquired by the British Museum by purchase from Dr. Krantz as from the Glandore Iron Mines, Co. Cork, in the year 1858; but the crystals and the matrix exactly resemble specimens from Dernbach, and do not agree in all respects with the Cork specimens in the British Museum.

The portion taken for analysis was carefully purified under the microscope. It was almost entirely free from inclusions, but a very small amount of quartz escaped notice. This, however, was separated in the course of analysis.

The beudantite occurs in dark green crystals, which present the appearance of nearly black cubes with slightly curved faces. They have a greenish yellow streak, and are pale green when viewed in thin fragments by transmitted light. The crystals line cavities in a jaspery limonite, which is traversed by a little white quartz. The back of the specimen is covered with botryoidal hæmatite converted into limonite.

Results of analysis:—

·5730 of a gram gave		·0032	insoluble residue	=	·56	per cent. residue
·5730	,, ,,	·2517	$PbSO_4$ ...	=	32·33	,, PbO
·5091	,, ,,	·0430	H_2O ...	=	8·45	,, H_2O
·5091	,, ,,	·1762	Fe_2O_3 ...	=	34·61	,, Fe_2O_3
·5091	,, ,,	·0069	CuO ...	=	1.35	,, CuO
·4591	,, ,,	·2211	$PbSO_4$ ...	=	12·72	,, SO_3
·4591	,, ,,	·0671	$Mg_2P_2O_7$ ...	=	9·35	,, P_2O_5[1]

(*d*) *Discussion of results.*

The numbers obtained agree very closely with those demanded by the formula $3PbSO_4.2FePO_4.6Fe(OH)_3$, or $3PbO.4Fe_2O_3.P_2O_5.3SO_3.9H_2O$.

Comparing the calculated percentages with those obtained by experiment, converting the CuO into its equivalent of PbO and reducing the numbers to 100, we get:—

	Calculated.	Found.
PbO ...	36·10 ...	35·69
Fe_2O_3 ...	34·51 ...	34·18
SO_3 ...	12·97 ...	12·56
P_2O_5 ...	7·67 ...	9·28
H_2O ...	8·75 ...	8·34
	100·00	100·00

[1] Containing a trace of As_2O_5.

Digitized by Google

It will be noticed on looking back to the previous analyses that three out of four analysts found about 12 per cent. of SO_3, while Müller alone obtained a much smaller quantity, and since both Müller and Percy analysed the Horhausen variety and obtained such different results, it seems reasonable to assume that the former either made some error in his analysis or else made it on some altogether different mineral.

It remains, therefore, to consider Percy's and Rammelsberg's results. Rammelsberg's numbers agree very well with the formula he suggested, which differs from the present one in having two equivalents of PbO instead of three.

Percy's analysis is more or less intermediate between Rammelsberg's and mine. The numbers obtained in his second analysis made on purified material compared with the numbers calculated from these two formulæ, of course replacing P_2O_5 by As_2O_5, are as follows:—

	Percy.	Calculated for $4Fe_2O_3.2PbO.3SO_3.As_2O_5.9H_2O$ (Rammelsberg)	Calculated for $4Fe_2O_3.3PbO.3SO_3.As_2O_5.9H_2O$ (Hartley)
PbO	29·52	25·96	34·46
Fe_2O_3	37·65	37·25	32·97
As_2O_5	13·60	13·39	11·85
SO_3	12·35	13·97	12·37
H_2O	8·49	9·43	8·35
	101·61	100·00	100·00

In spite of these results, the formula suggested in this paper, which may be written $3(Pb,Cu)SO_4.2Fe(P,As)O_4.6Fe(OH)_3$, seems the most probable, the following points being in its favour:—

(i) The material used was, with the exception of a little quartz, almost absolutely free from visible impurities, and sufficient quantity was available for a reliable analysis.

(ii) The formula is very much simpler than Rammelsberg's, the equivalents of acids and bases corresponding to one another, and the water fitting in with the extra amount of ferric oxide to give the simplest hydrate.

(iii) The higher percentages of iron in previous analyses can easily be accounted for by the fact that the mineral is in many cases closely associated with particles of ferric oxide, which are somewhat difficult to remove.

Digitized by Google

Communications from the Oxford Mineralogical Laboratory.

Note on the Hitchcockite, Plumbogummite and Beudantite analysed by Mr. Hartley.

By Professor H. A. Miers, M.A., F.R.S.

[Read January 23rd, 1900.]

Hitchcockite and Plumbogummite.

In a description of some British pseudomorphs, published in 1896 (*Mineralogical Magazine*, XI, p. 272), I mentioned that the sky-blue and lavender-blue mineral sometimes found encrusting the pyromorphite from Roughten Gill is not a zinc carbonate or silicate, as commonly supposed, but is a phosphate of lead and aluminium. Pseudomorphs of this substance after pyromorphite are not rare among Roughten Gill specimens, and these were described in the above-mentioned paper as examples of plumboresinite after pyromorphite.

Mr. E. G. J. Hartley, having at my suggestion undertaken the analysis of this mineral, made also analyses of the original plumboresinite (or plumbogummite) from Huelgoat, and of the hitchcockite from Georgia, which has generally been regarded as a variety of plumbogummite, with the view of comparing them with the Cumberland mineral. He has shown that the latter is identical with the mineral from Georgia. The pseudomorphs should, therefore, be described as of *hitchcockite after pyromorphite*.

The Cumberland Hitchcockite.—This beautiful blue substance occurs as a crust which generally lies directly upon the vein quartz, and usually has crystals of pyromorphite dispersed upon it. The pyromorphite crystals are sometimes quite fresh, but are often surrounded by a zone of hitchcockite, and on some specimens are only represented by hollow pseudomorphs consisting entirely of hitchcockite; these last are of a pale blue, or in some instances of a greenish yellow colour; but the ordinary colour of the crust is a rich smalt- or lavender-blue.

The surface of the crust is rough, and under the microscope it is seen to consist of minute crystals with pyramidal terminations. These are too small to be measured.

Between crossed nicols the crust gives aggregate polarisation, and is seen to consist of radiating needles. The underlying portions exhibit a

Digitized by Google

botryoidal structure, and when thin the crust shows the black crosses characteristic of spherulites. The effect produced by a thin piece of this crust viewed transversely in parallel light between crossed nicols is very beautiful, owing to the perfection of these crosses and the bright polarisation tints of the radii.

When crushed and examined in oil, the fibres of which the crust consists are seen to have straight extinction and to be elongated in the positive direction. In convergent light they appear to be either positive uniaxial crystals or biaxial with a very small axial angle and elongated along the positive acute bisectrix; but these observations are very difficult. The refractive power and the bi-refringence are distinctly less than those of pyromorphite.

A thin portion of the crust viewed in convergent light sometimes gives an effect closely resembling a positive uniaxial interference figure, but really due to the radial fibrous structure.

The pyromorphite and mimetite from Cumberland, with which hitchcockite is associated, seem to have been found at several of the lead workings in the neighbourhood of Roughten Gill, a small stream nearly three miles south of the village of Caldbeck. The workings have been practically abandoned for many years; the specimens which now adorn most collections seem to have been obtained shortly before the year 1834.

At a distance of a few hundred yards from each other are the workings, which were known from the streams upon which they are situated as Roughten Gill and Red Gill. Among the minerals found at the former have been recorded campylite, aurichalcite, pyromorphite, brochantite, anglesite, melaconite and various copper ores, calamine (smithsonite), psilomelane, chalcedony, barytes, and linarite. Among the minerals recorded from Red Gill are malachite and other copper ores, cerussite, leadhillite, caledonite, and linarite.

The chief sources of information on this subject are:—

Greg and Lettsom, *Mineralogy of Great Britain and Ireland*, 1858.

Bryce M. Wright, in Jenkinson's *Practical Guide to the English Lake District*, 1885, pp. lxxi-xcvii, where a very full list of localities is given.

J. G. Goodchild, "Contributions towards a List of the Minerals occurring in Cumberland and Westmoreland" (*Transactions of the Cumberland Association for the Advancement of Literature and Science*, Part VII, 1883, pp. 101-126; Part VIII, 1884, pp. 189-204; Part IX, 1885, pp. 175-199).

The reference in Dana's *System of Mineralogy*, 1850, to Roughten Gill

Digitized by Google

as a locality for plumboresinite probably relates to the brown resinous pyromorphite (perhaps one of the aluminous varieties), for the brilliant blue colour of the mineral is not alluded to.

Hitchcockite from Canton Mine, Georgia.—In the specimen analysed by Mr. Hartley this mineral occurs in nearly colourless crusts upon a matrix consisting mainly of quartz, galena, pyrites and chalcopyrite. Although so different from the Cumberland mineral in colour, it resembles it in every respect so far as its essential properties are concerned, and is absolutely indistinguishable from it under the microscope; the surface, the structure, and the optical characters are exactly as described above. Hitchcockite has been described as uniaxial and positive by E. Bertrand (*Bull. Soc. Min*, 1881, IV, 37).

Plumbogummite from Huelgoat, Brittany.—The specimen analysed by Mr. Hartley consisted of deep brown resinous botryoidal plumbogummite, which in parts showed a roughly facetted surface like that of some botryoidal hæmatite, but it was for the most part devoid of any definite radial structure. The plumbogummite was in contact with a pale brownish-yellow mineral of resinous lustre and fibrous structure, whose surface when botryoidal closely resembles that of the plumbogummite. The matrix consisted of galena and massive pyrites.

Viewed under the microscope no portion of the specimen shows the typical black crosses of hitchcockite. Where at all fibrous, the brown plumbogummite is seen to have a *positive* elongation and straight extinction; a positive uniaxial interference figure was obtained from some fragments. Both the refraction and the double refraction of this mineral are higher than those of the Cumberland and American hitchcockite, and are greater than those of pyromorphite. The mineral is also harder than hitchcockite.

The pale-coloured mineral upon this specimen is probably a variety of pyromorphite, for in one part it contains a small cavity lined with microscopic crystals. I was able to isolate one of these, and to measure it on the 2-circle goniometer. It proved to be a hexagonal prism terminated by the basal plane and six faces of a pyramid on the corners of the latter; the angle between pyramid and base is 39°38′ (38°55′–41°11′); the corresponding angle for pyromorphite is 40°22′. This crystal, like the pale material in general, was elongated in the *negative* direction; the mineral is also softer than the brown plumbogummite, and possesses weaker birefringence.

Digitized by Google

The optical examination of the above minerals, therefore, confirms Mr. Hartley's analysis in an interesting manner, for it shows that, although the three specimens resemble each other in some respects, the Cumberland and American minerals (hitchcockite) are absolutely indistinguishable, whereas they differ in most particulars from plumbogummite, and can easily be distinguished from it; also that the plumbogummite is quite distinct from the pale mineral (pyromorphite) with which it is associated. The microscope however fails to reveal any mechanical mixture of the two; the fragments of plumbogummite appear remarkably homogeneous and free from impurity.

Beudantite.

The specimen of beudantite analysed by Mr. Hartley professes to be from the Glandore mines in County Cork, and was bought as such from Dr. Krantz only two years after his discovery of the mineral at that locality. The appearance of the specimen resembles more closely specimens from Dernbach than the other specimens from Glandore which I have been able to see, but, since the matrix only contains limonite and quartz, the superficial appearance of the beudantite alone is not sufficient to disprove its Irish origin; neither does Mr. Hartley's analysis clear the doubt, for the percentage of phosphoric acid which he finds is about midway between that found by Müller in Dernbach beudantite and that found by Rammelsberg in the Cork mineral.

Under the microscope fragments of the beudantite from this specimen are indistinguishable from either the Dernbach or the Cork beudantite. Of the former there is a specimen in the Oxford Museum, and through the kindness of Mr. H. J. Seymour I have had the opportunity of examining a specimen of the latter belonging to University College, Dublin, which came from the collection made by the late Dr. Sullivan.

Fragments of all these are pale yellow or yellowish-brown, when sufficiently thick. They are easily distinguished from pharmacosiderite, which is green, and invariably exhibits a banding parallel to the cube faces. The beudantite possesses a stronger birefringence than pharmacosiderite, and does not show the same cubic banding; it does, however, sometimes exhibit a lamellar structure, and it shows frequent evidences of twinning, many fragments consisting of differently orientated birefringent material. For this reason, though brushes may be seen, it is very difficult to say whether the mineral is uniaxial or biaxial. One fragment presented what appeared to be the negative bisectrix of a biaxial crystal with large optic axial angle. E. Bertrand (*Bull. Soc. Min. Franc.* 1881,

Digitized by Google

IV, 255) also found the beudantite from Dernbach, Cork and Horhausen to be indistinguishable under the microscope; but found them to be uniaxial and negative. I have not been able to find a definite uniaxial figure in any of the fragments which I have examined.

One minute crystal from Dernbach with very brilliant rhombohedron faces gave the angle 88°22′ for the rhombohedron angle. Dauber found 88°42′ as the mean of all his measurements.

Digitized by Google

Florencite, a new hydrated Phosphate of Aluminium and the Cerium Earths, from Brazil.

By Dr. E. Hussak, of the Geological Survey of S. Paulo; and
G. T. Prior, M.A., F.G.S.,
Assistant in the Mineral Department of the British Museum.

[Read Nov. 14th, 1899.]

Occurrence.

FLORENCITE was first discovered as a rare constituent of the cinnabar-bearing sands of Tripuhy, near Ouro Preto, Minas Geraes, Brazil. Here it occurred in well-developed crystals (up to ½ cm. in length), in association with monazite, xenotime and the titano-antimonates (lewisite and derbylite) previously described.[1] Blowpipe experiments made by Dr. W. Florence showed that the mineral was a phosphate of the cerium earths, while angular measurements of the crystals and observations of the optical characters suggested its close relationship with hamlinite, the new hydrated phosphate of aluminium, barium and strontium, recently described by Hidden and Penfield.[2] From this locality it was not possible to pick out sufficient material for quantitative analysis. In much larger amount, however, and in larger crystals and rounded grains, the same mineral was found later in a sample of diamond-bearing sand from "Matta dos Creoulos" on the Rio Tequetinhonha, near Diamantina, Minas Geraes, which was collected by Prof. O. A. Derby. The material used in the quantitative chemical analysis was from this source. It consisted of acute rhombohedral crystals, the angular measurements and optical properties of which were in perfect agreement with those of the mineral from Tripuhy.

A third source of the new mineral is the Morro do Caixambú, the well-known locality of the yellow topaz near Ouro Preto and Tripuhy. Here it was found in relatively large amount as a microscopic accessory constituent of the reddish micaceous schists, in the quartz lenticles of which

[1] *Min. Mag.* XI, 80, 176 (1896–7).
[2] *Am. J. Sci.* 1890, XXXIX, 511, and 1897, IV, 313.

Digitized by Google

occurs the topaz in association with kaolin and hæmatite. Examination of the microscopic crystals, which had been obtained by Prof. O. A. Derby in the heavy residue of the schists, showed that they were rhombohedral and optically uniaxial, and that they contained phosphoric acid and cerium earths. There is therefore little doubt of their specific identity with the mineral from Tripuhy and "Matta dos Creoulos."

Crystallographic and other physical characters (E. H.).

The crystal system of florencite is rhombohedral (trigonal, ditrigonal-scalenohedral class of Groth).

Axial ratios (calculated from $r'r'''$):—$a : \dot{c} = 1 : 1{\cdot}1901$.

Observed forms and combinations:—

$r = R,(10\bar{1}1)$, rare.
$f = -2R,(02\bar{2}1)$, the predominant form with
$c = 0R,(0001)$.
$m = \infty R,(10\bar{1}0)$, very rare,

and an obtuse positive rhombohedron, probably $+\frac{1}{2}R(0112)$.

Measured angles:—

$f'r'$	=	54°13′, very good reflections.
$r'f''$	=	54°11′.
$f''r''$	=	54°13′, very good reflections.
$r''f'''$	=	54°18′.
$f'''r'''$	=	54°14′.
$r'''f'$	=	54°20′.
$f'f''$	=	108°26′.
*$r'r'''$	=	88°56′.

These angles correspond very closely with those given by Penfield for hamlinite, as seen in the following table:—

	Florencite (Hussak).			Hamlinite (Penfield).
$r'r'''$	= 88°56′	...	...	87°2′
$f'f''$	= 108°26′	...	...	108°2′
$r'f'$	= 54°13′	...	...	54°1′
$a : \dot{c}$	= 1 : 1·1901	...	...	1 : 1·1853

The rhombohedral faces are generally bright, and give good reflections. The basal plane, on the other hand, is rough and much curved.

Cleavage: basal, fairly perfect. The fracture is splintery to sub-conchoidal. The hardness is about 5. The specific gravity (weight of one cc.)

Digitized by Google

of the material used for analysis was 3·586 at 17°, as determined on 0·5601 gram. The lustre is greasy to resinous. The colour of the pure mineral is clear pale yellow, but the crystals are often spotted black by included microsccpic needles of tourmaline, or are coloured red by oxide of iron. The mineral is transparent, and is optically uniaxial and positive. The double refraction is not very strong.

Chemical Composition (G. T. P.).

The mineral is infusible. Heated in the closed tube it gives off acid water, and leaves signs of etching on the tube. As in the case of hamlinite, very strong ignition is necessary before all the water is expelled:[1] 0·2043 gram gave off no water at 130°, and only lost ½ m.gr. after heating for an hour and a half up to 240°.

The mineral appeared to be only partially soluble in hydrochloric acid, a residue being always left even after prolonged digestion. Qualitative analysis showed the presence of phosphoric acid, cerium earths, alumina, water, and somewhat doubtfully of fluorine: no beryllia, yttria earths, thoria or zirconia could be detected.

The results of the quantitative analyses are as follows:—

	I.	II.	III.	Mean.	Mol. Ratios.	Hamlinite (Penfield)
Al_2O_3 ...	= 32·05	—	32·52	32·28	·316	32·30
Ce earths	= 28·20	—	27·80	28·00	·080	—
(Molecular weight = 352[2])						
Fe_2O_3 ...	= 0·76	—	—	0·76	—	·90
CaO ...	= 1·31	—	—	1·31	—	—
SiO_2 ...	= 0·48	—	—	0·48	—	·96
P_2O_5 ...	= 25·08	—	26·04	25·61	·181	28·92
H_2O ...	= —	10·87	—	10·87	·604	12·00
(Loss on ignition)						
F ...	= undet.			99·31		1·93
					SrO	18·43
					BaO	4·00
					Alkalies	·74
						100·18

[1] An attempt to determine the water directly by igniting the mineral in a porcelain boat in a combustion tube failed owing to the fact that in this way it could not be heated to a sufficiently high temperature.

[2] Two determinations of the molecular weight were made, one on 0·0743 gr. and the other on 0·1113 gr. of the ignited oxide, by converting into sulphate and precipitating the sulphuric acid with barium chloride. The two results were in close agreement (352·2 and 352·7), but give a number which is considerably higher than those usually accepted for any of the cerium earths. Examination of the absorption spectrum of a solution of the sulphate suggested that didymium was only present in very small amount, as the characteristic bands in the green and yellow were only faintly visible.

Digitized by Google

Weight of material used in I, 0·8289 gram; in II, 0·1545 gram; in III, 0·2048 gram.

Method of Analysis.—The portion soluble in hydrochloric acid and the insoluble residue were treated separately, but the composition of the two appeared to be practically the same. In the soluble portion the cerium earths were precipitated by oxalic acid, the alumina and part of the phosphoric acid in the filtrate by ammonia, and the rest of the phosphoric acid by magnesia mixture. In this way, however, by no means perfect separations were effected, so each precipitate was separately treated, and the phosphoric acid in it determined by the molybdate method. The insoluble portion was fused with sodium carbonate, and the portion soluble in water and the residue were separately treated in the same way as the original solution, in the case of all the precipitates the phosphoric acid being finally determined by the molybdate method. The loss on ignition was determined in a separate portion by igniting with lime according to Penfield's method.[1] A determination of the loss on ignition without the use of lime gave 11·50 per cent.

The cerium earths, which on ignition were of a deep brownish red colour, were tested for yttria earths by converting into sulphates and precipitating with potassium sulphate: in the filtrate only a slight precipitate was obtained with oxalic acid. No precipitate was obtained with sodium thiosulphate in the solution of the sulphate.

The numbers obtained, considering the probability that by the method of analysis on so small an amount of material the alumina may be somewhat over and the phosphoric acid under estimated, suggest the formula—

$$8Al_2O_3.Ce_2O_3.2P_2O_5.6H_2O, \text{ or } AlPO_4.CePO_4.Al_2(OH)_6$$

analogous to that given to hamlinite by Penfield—

$$8Al_2O_3.2(Sr,Ba)O.2P_2O_5.7H_2O,$$

in which part of the HO is replaced by F.

The chemical composition of florencite is thus very similar to that of hamlinite, the strontia and baria of the latter being in florencite replaced by cerium earths.

The result of the analysis is, therefore, to support the idea suggested by the similarity in crystallographic and optical properties, cleavage, &c., that the two minerals are really isomorphous.

---

[1] *Am. J. Sci.* 1897, IV. 314.

Digitized by Google

This result is of interest in view of the researches of Wyrouboff and others,[1] who have shown the isomorphism of many cerium salts with corresponding salts of calcium and strontium, and have based on these facts arguments for the diad character of the cerium earths.

[1] Wyrouboff, *Bull. Soc. Min.* 1896, XIX, 282; Cossa, *Compt. Rend.* XCVIII, 1884, 990; *Accad. d. Lincei*, 1878 and 1879 [3] and 1886 [4].

Digitized by Google

Hamlinite, Florencite, Plumbogummite (Hitchcockite), Beudantite and Svanbergite, as members of a natural group of minerals.

By G. T. Prior, M.A., F.G.S.,
Assistant in the Mineral Department of the British Museum.

[Read April 3rd, 1900.]

In mineralogical literature there appears to be a tendency to over-estimate the degree of exactness attainable in the chemical analysis of minerals. When it is considered how impossible in the majority of cases it is to obtain absolutely pure material for analysis, and how imperfect even in these days are some of the methods of chemical separation employed, for the determination of a formula any great reliance in the figures to the right of the decimal point in the percentages obtained is scarcely justified in the case of analyses made on small amounts (less than half a gram) of material. In such cases also impurities, derived from the reagents and from the glass and porcelain vessels used in the course of a prolonged analysis, become of importance, and in some cases at least may possibly account for the small fractional percentages of lime, iron and alkalies, which, for example, are often seen figuring in analyses of complex niobates.

Some slight protest, therefore, against any over-estimation of the exactness of mineral analysis seems at the present time to be necessary, since otherwise there is danger that simple formulæ may be sometimes unnecessarily rejected in favour of more complex ones agreeing somewhat more closely with the numbers obtained in the analysis, the result of which may be that the mutual relations of analogous species are obscured.

In the case of complex minerals the results of analysis may suggest several formulæ, all of which agree with the numbers obtained within say one per cent. for any of the constituents.

In the choice of a formula, therefore, account must be first taken of the amount of material used in the analysis and of the methods employed,[1] in order to be able to form a judgment of the reliability of the numbers within one per cent.

[1] It is to be regretted that in the published descriptions of mineral analyses these data have been so often omitted.

Digitized by Google

The possible relationship of the mineral to other species must then receive consideration. The application of such theoretical considerations in the choice of a formula to old analyses made by imperfect methods may have its dangers, since the numbers may be often very wide of the truth. In the case of recent analyses, however, such as those of Hartley on plumbogummite and beudantite (see p. 223), made by modern methods on carefully purified material, we have perfectly suitable material on which to base theories.

In the following note, accordingly, I propose to bring forward some considerations which make it appear probable that these minerals and also svanbergite belong to the same group of aluminium phosphates as hamlinite and florencite.[1]

Plumbogummite (Hitchcockite).

This mineral has hitherto been found only in fibrous radiating aggregates, and not in definite crystals. Hartley, as the result of his analyses (see p. 230) concludes that the hitchcockite from Georgia and from Roughten Gill is a definite mineral, and that probably the original plumbogummite from Huelgoat is an impure mixture of hitchcockite and pyromorphite. It seems reasonable, however, judging from the variations (as much as 2 per cent. in some of the constituents) in the analyses even of hitchcockite alone, to suppose that in none of these fibrous aggregates have we the true species in a pure state.

I would suggest, therefore, that the true species belongs to the same group as hamlinite and florencite, and has the chemical formula

$$2PbO{\cdot}3Al_2O_3{\cdot}2P_2O_5{\cdot}7H_2O$$

analogous to that of hamlinite $2(Sr,Ba)O{\cdot}3Al_2O_3{\cdot}2P_2O_5{\cdot}7H_2O$.

As seen below, the numbers obtained by Hartley in the case of the Roughten Gill mineral show some approach to the theoretical numbers required for this formula.

Thus:—

	Hitchcockite (Roughten Gill).		Calculated for $2PbO{\cdot}3Al_2O_3{\cdot}2P_2O_5{\cdot}7H_2O$
PbO	37·03	...	38·34
Al_2O_3	28·74	...	26·37
P_2O_5	18·64	...	24·44
CO_2	3·12	21·77	
H_2O	12·73	...	10·85
	100·26		100·00

[1] On the mutual relations of florencite and hamlinite, see preceding paper (p. 247).

Digitized by Google

As regards the physical relations of plumbogummite to hamlinite we have the observation of Bertrand that the mineral is uniaxial and positive, and in accordance with this view in hitchcockite the fibres are positive, and compensate with the quartz wedge across their length. In the case of the paler coloured variety of the French mineral, however, compensation takes place along the length of the fibres, and this observation may have some connection with Hartley's conclusion that the plumbogummite specimens from Huelgoat consist largely of pyromorphite, which is optically negative.

Beudantite.

In the case of this well-crystallised mineral, evidence of its connection with the hamlinite-florencite group is of a more satisfactory character than in the case of plumbogummite.

Instead of Hartley's formula, $4Fe_2O_3 \cdot 3PbO \cdot 3SO_3 \cdot P_2O_5 \cdot 9H_2O$ (see p. 237), I would propose $2PbO \cdot 3Fe_2O_3 \cdot P_2O_5 \cdot 2SO_3 \cdot 6H_2O$, corresponding to that of hamlinite, $2(Sr,Ba)O \cdot 3Al_2O_3 \cdot 2P_2O_5 \cdot 7H_2O$, with one molecule of P_2O_5 replaced by two of $SO_3(S_2O_6)$. This formula may be also written $PbSO_4.FePO_4.Fe_2(OH)_6$ corresponding to hamlinite (regarded as an orthophosphate instead of a pyrophosphate) $SrHPO_4.AlPO_4.Al_2(OH)_6$, with the grouping $SrHPO_4$ replaced by $PbSO_4$ and Al by Fe (see p. 253). The numbers obtained by Hartley agree fairly closely with the theoretical numbers required for the above formula. Thus:—

	Beudantite (Hartley).	Calculated for $2PbO \cdot 3Fe_2O_3 \cdot P_2O_5 \cdot 2SO_3 \cdot 6H_2O$.	Calculated for $4Fe_2O_3 \cdot 3PbO \cdot 3SO_3 \cdot P_2O_5 \cdot 9H_2O$
PbO ...	32·33	33·37	36·10
CuO ...	1·35	—	—
Fe_2O_3 ...	34·61	35·93	34·51
SO_3 ...	12·72	11·99	12·97
P_2O_5 ...	9·35	10·63	7·67
H_2O ...	8·45	8·08	8·75
	98·81	100·00	100·00

The close crystallographic connection of beudantite, and also of svanbergite, with hamlinite and florencite, is evident from the fact that they all crystallise in the rhombohedral system, and show a fairly perfect basal cleavage, and that corresponding angles, as seen in the following table of measured angles, show only slight variations.

Digitized by Google

Thus :—

	Hamlinite.	Florencite.	Beudantite.	Svanbergite.
cr =	52° 40′	—	58° 49′	54° 19′
cf =	69 7	—	69 55	70 15
rr' =	87 2	88° 56′	88 42	89 25
ff' =	108 2	108 26	ss'108 51	ss'109 12

Svanbergite.

As seen above, svanbergite is crystallographically very similar both to beudantite and also to hamlinite and florencite.

To what extent the mineral is also chemically analogous is seen from Blomstrand's analysis of a specimen from Westanå, the result of which was as follows :—

			Molecular ratios.	
P_2O	...	15·70	·1108	or 1·108
SO_3	...	15·97	·2000	2·000
Al_2O_3	...	34·95	·3428	3·428
FeO	...	0·73	·0102	3·303
PbO	...	3·82	·0172	
MgO	...	0·24	·0060	
CaO	...	16·59	·2969	
H_2O	...	12·21	·6799	6·799
		100·21		

These numbers correspond approximately with a formula —

$$3CaO{\cdot}3Al_2O_3{\cdot}P_2O_5{\cdot}2SO_3{\cdot}6H_2O,$$

which only differs from $2CaO{\cdot}3Al_2O_3{\cdot}P_2O_5{\cdot}2SO{\cdot}6H_2O$ analogous to the beudantite formula by containing 3 molecules of CaO instead of 2. The close agreement with theory, except in this one respect, therefore, suggested the idea that Blomstrand's 16 per cent. of CaO may have been partly made up of SrO or BaO of higher molecular weight.

A chemical examination was accordingly made of a specimen of svanbergite from Westanå in the Museum collection. The alkaline earths separated from phosphoric acid and alumina were precipitated by ammonium carbonate; the carbonate was converted into nitrate, which was found to be insoluble in a mixture of alcohol and ether, and to consist almost wholly of the strontium and not of the calcium salt. The chloride gave a good strontium flame in the Bunsen. Examined with the spectroscope the bands in the red were seen to be identical with those given by a strontium salt, while the bright green line characteristic of calcium was only once or twice for an instant just faintly visible.

Digitized by Google

If in Blomstrand's analysis we replace the calcium by strontium, the numbers and molecular ratios are as follows:—

				Molecular ratios.	
P_2O_5	...	15·70	...	·1108	or 1·108
SO_3	...	15·97	...	·2000	2·000
Al_2O_3	...	34·95	...	·3428	3·428
FeO	...	0·78	...	·0102	1·941
PbO	...	3·82	...	·0172	
MgO	...	0·24	...	·0060	
SrO	...	16·59	...	·1607	
H_2O	...	12·21	...	·6799	6·799
		100·21			

These numbers agree fairly closely with the formula

$$2SrO.3Al_2O_3.P_2O_5.2SO_3.6H_2O,$$

which is analogous to that of hamlinite with one molecule of P_2O_5 replaced by two of SO_3. Svanbergite thus bears a similar relation to hamlinite that beudantite does to plumbogummite.

Summary.

In this note it is suggested that the following minerals belong to a natural group:—

	Formula.	Cryst. System.	rr'. Axial ratio.
Hamlinite.....	$2SrO.3Al_2O_3.2P_2O_5.7H_2O$	Rhombohedral	87°2′ $c=1·1353$
Svanbergite	$2SrO.3Al_2O_3.P_2O_5.2SO_3.6H_2O$	,,	89°25′ $c=1·2063$
Plumbogummite	$2PbO.3Al_2O_3.2P_2O_5.7H_2O$	,,	—
Beudantite.....	$2PbO.3Fe_2O_3.P_2O_5.2SO_3.6H_2O$	,,	88°42′ $c=1·1842$
Florencite	$Ce_2O_3.3Al_2O_3.2P_2O_5.6H_2O$	,,	88·56′ $c=1·1901$

The suggestion that in these minerals such a group as $2SO_3$ or S_2O_6 can replace P_2O_5 without materially affecting the crystalline form is similar to that made by the author in the case of members of the fahlerz group (see this volume, page 203), viz. that 6FeS may replace $3Cu_2S$. If, however, the formula of hamlinite be written in the form

$$SrHPO_4.AlPO_4.Al_2(OH)_6$$

as an ortho- instead of a pyro-phosphate, the grouping $SrHPO_4$ may be considered as replaced in beudantite by $PbSO_4$, in svanbergite by $SrSO_4$, and in florencite by $CePO_4$ without materially affecting the crystalline form. According to this view the most probable formula for florencite would be $CePO_4.AlPO_4.Al_2(OH)_6$: for beudantite, $PbSO_4.FePO_4.Fe_2(OH)_6$; and for svanbergite $SrSO_4.AlPO_4.Al_2(OH)_6$.

Digitized by Google

It is probable that many of the imperfectly described complex phosphates and arsenates of iron, manganese or aluminium may have a similar type of formula to that of the above group. For many of these complex phosphates new analyses made by modern methods on pure material are required.

Digitized by Google

Ægirine and Riebeckite Anorthoclase Rocks related to the "Grorudite-Tinguaite" series, from the neighbourhood of Adowa and Axum, Abyssinia. [Plate III.]

By G. T. Prior, M.A., F.G.S.,

Assistant in the Mineral Department of the British Museum.

[Read April 3rd, 1900.]

Introduction.
Description of Profiles.
Description of the Rock-specimens:—
The Grorudites:
The Paisanite.
The Sölvsbergites.
The Tinguaites.
The Trachyte and Pitchstone.
The Dolerites and Basalts.
Conclusions, and comparison with other African rocks.

IN 1869 the late Dr. Sadebeck[1] gave a brief description of a collection of rocks, accompanied by a map and profiles, made by Dr. W. Schimper in the neighbourhood of Adowa and Axum, Abyssinia.

In the British Museum is a very similar collection, which was purchased from Dr. Schimper about the same time. As some of these rocks showed points of resemblance to the riebeckite-trachytes of Senafé, recently described by the author,[2] a somewhat more detailed petrographical examination of the specimens than Dr. Sadebeck was able to afford them appeared to promise something of interest.

The main result of that examination has been to show that the hills in this district of Abyssinia, with a few exceptions where dolerites occur, consist largely of ægirine- (or riebeckite) felspar rocks (with or without quartz or nepheline), which are closely related to the *grorudite-tinguaite* series of the Christiania District described by Brögger.[3]

The Museum collection is accompanied by profiles on which the

[1] *Zeits. Ges. f. Erdkunde*, IV, 1869, pp. 347–52.
[2] *Min. Mag.* 1899, XII, 92.
[3] Brögger, *Eruptivgesteine des Kristianiagebietes*, I.

Digitized by Google

locality of each rock is marked by a number corresponding to that on the specimen. These profiles are similar to those which are figured in Sadebeck's paper, but are reproduced here in slightly different form in order to illustrate the text, and also to correct certain inaccuracies in the nomenclature of some of the rocks, into which Dr. Sadebeck was led owing, apparently, to the want of a microscopic examination of his specimens.

The small diagrammatic sketch map (fig. IX) is a rough reproduction of the one made by Dr. Schimper, and shows the two main lines of country from which the specimens were collected, viz. *B A*, north to south, from the banks of the R. Mărăb to Amba Semajata; and *K L*, west to east, from Amba Gollo to Amba Hedscha.

DESCRIPTION OF THE PROFILES (pp. 258-9).

Profile I.—B-A, north to south, from the banks of the River Mărăb (*B*), 4,000 ft. to Amba Semajata (*A*), 9,800 ft.

The granite (1) on the banks of the Mărăb is a pale pink medium-grained rock, the felspar of which consists principally of microcline; biotite is present only in small amount. This rock is succeeded along the Hamedo Plain by biotite-gneiss (2 *a*, 3 and 4), micaceous phyllites (2 *b*), and hornblendic schists (2 *e*). Phyllite (2 and 11), with here and there a deep red ferruginous breccia (laterite, 5), claystone (10), and in Gadema Keflahit coarse sandstone (9), is the prevailing rock below the level of 7,000 ft. from the District of Schahagăne to Amba Semajata. Where the level of the country rises above 7,400 ft. in the mountains, Amba Subhat (8,600 ft.), Amba Bató (7,400 ft.), Gossoso (7,900 ft.), and Amba Semajata (9,800 ft.), the phyllites are broken through, with marked tilting of the strata, by ægirine-felspar rocks (6, 12, 13, 14 respectively, the "younger granites" of Sadebeck), which I have referred to the "grorudite" and "sölvsbergite" of Brögger, since they present the characters of intrusive hypabyssal rocks rather than those of lava flows.

Profile II.—C-D, across the Hamedo Plain, cutting Profile I at Keren. This profile shows only dark biotite-gneiss (3 and 4), hornblende schist and phyllite (2).

Profile III.—E-F, parallel to I, in Schahagăne and Achsa Districts, from Abuna Alif (6,500 ft.) to Amba Bachele (6,390 ft.).

The rocks 7 and 8, of which, according to Schimper, these hills consist, are ægirine-felspar (anorthoclase) rocks, which I have referred to

Digitized by Google

the "sölvsbergite" of Brögger. Between the two hills occur phyllites (Urthonschiefer) covered with pebbles of rocks 7 and 8 and of laterite. Sadebeck refers to a hornblende-bearing gneiss in this profile, and to porphyry raising the schists at Amba Bachele, but states that Schimper gives no porphyry on Abuna Alif. The sölvsbergite (7), with its rather platy structure, due to the arrangement of the felspars, appears to have been mistaken for a gneiss.

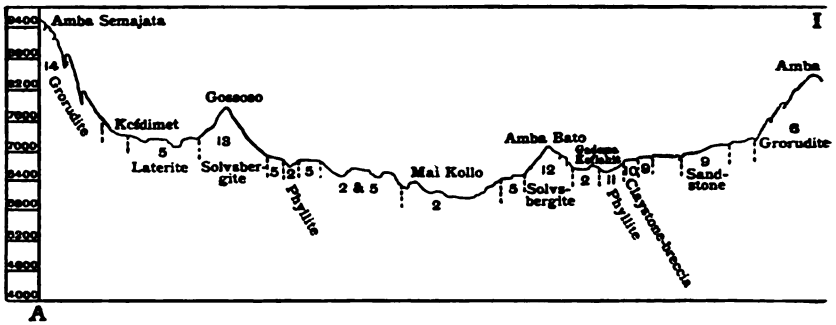
Profile IV.—G-H, across Mt. Scholoda, N. of Adowa.

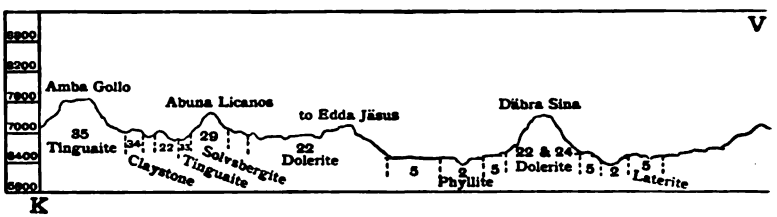
Mt. Scholoda consists of a quartz-anorthoclase-riebeckite rock similar to the "Paisanite" of Osann from Texas and to the Mynydd Mawr rock of North Wales. This rock (51-54) has been intruded through purplish phyllites (46-50). Near the contact the "paisanite" is very compact, and shows no phenocrysts of quartz and felspar. Near Adowa, at the foot of the mountain, the phyllites pass into gray roofing clay-slate (45).

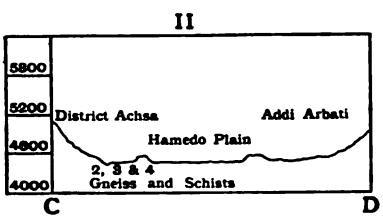
Profile V.—L-K, east to west, from Amba Hedscha to Amba Gollo, cutting Profile I in Amba Subhat.

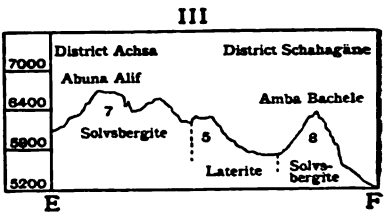
A rock (15) from the uppermost part of Amba Hedscha (9,400 ft.) shows porphyritic anorthoclase, and presents rather the characters of a flow than of an intrusive rock. It is very similar to the riebeckite-trachyte of Kishyat near Senafe (see *Min. Mag.* 1899, XII, 94), but the iron silicate has been wholly altered to ferrite. The slopes of Amba Hedscha (20), as well as the slopes (18) and top (19) of Arbaatu Ensesa (8,500 ft.) are composed of an ægirine-felspar rock allied to "sölvsbergite." Sadebeck only refers here to hornblende-bearing schists. Between Arbaatu Ensesa and Amba Herres the country is marked by Schimper as not examined. Amba Herres consists of basalt (17). At Magdalai also occurs dark green compact basalt (16) with iron pyrites. Beyond Magdalai, where the level drops to 6,200 ft., the schists (2) again make their appearance. On the slopes of Amba Subhat is the laterite (5); at Ganef with the laterite is also a coarse-grained ophitic dolerite (22). At the foot of Amba Berrach, where the level sinks below 7,000 ft., schists (2) are again seen. From Amba Berrach (7,400 ft.) are specimens of both grorudite (23) like the rock (14) from Amba Semajata, and also of the more basic sölvsbergite. Then follow schists (2) with laterite, where the level again falls to 6,300 ft. From Dăbra Sina (7,400 ft.) comes ophitic dolerite (24 and 22) like that of Ganef. Beyond Dăbra Sina occur laterite and once more the schists (2), where the level sinks to 6,300 ft. At the point marked "to Edda Jasus"

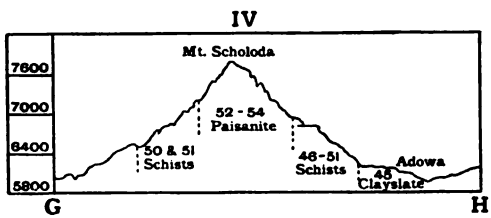
Digitized by Google

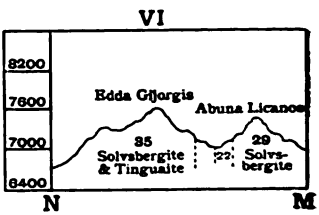


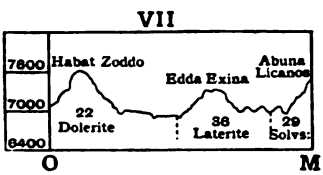


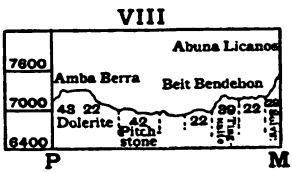




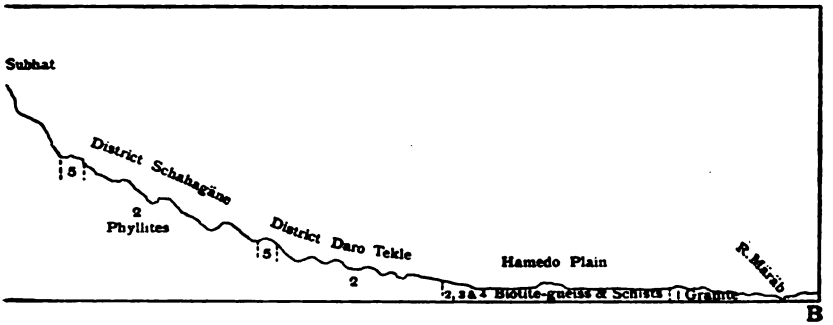


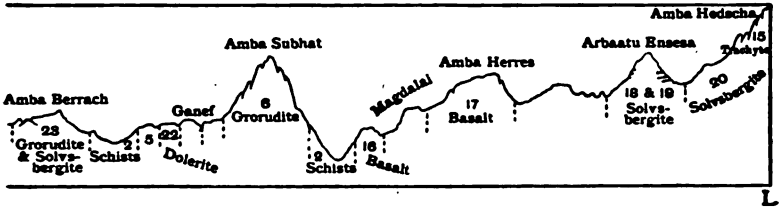




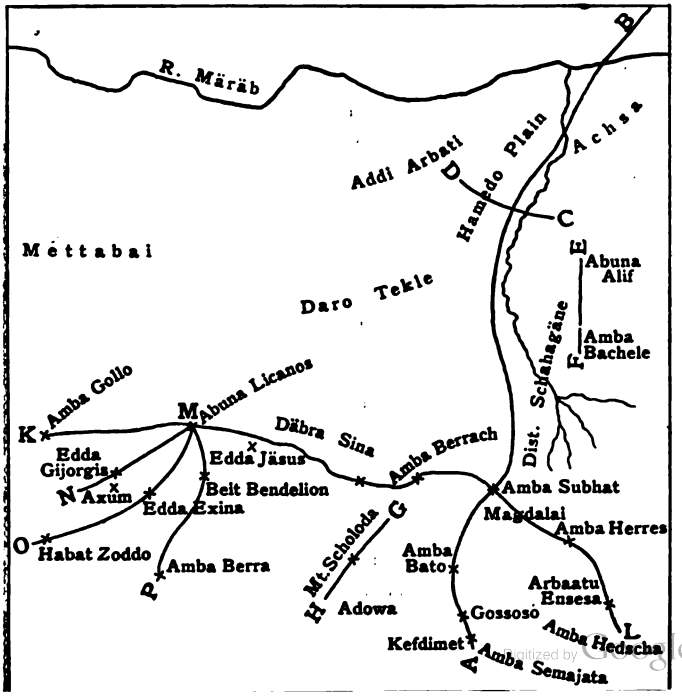


Digitized by Google





IX



Digitized by Google

dolerite (22) occurs again, and continues almost up to Abuna Licanos. At the foot of this hill is a dense glassy basalt (26). Abuna Licanos consists of an ægirine-felspar rock (29), sölvsbergite. Between Abuna Licanos and Amba Gollo occur alternately dolerites (22) and rocks (32, 33) containing both riebeckite and ægirine, with porphyritic nephelines, which I have referred to "tinguaites." Amba Gollo consists of tinguaite (35).

Throughout this profile schists (2) are only marked as occurring in four places, where the level sinks below 6,800 ft. Sadebeck refers the rock from Abuna Licanos to gneiss, but mentions that one would have expected an eruptive rock.

The three remaining profiles proceed from Abuna Licanos.

Profile VI.—M-N, Abuna Licanos to Edda Gijorgis. Edda Gijorgis consists of an ægirine-anorthoclase rock (sölvsbergite, 35*b*); an ægirine-felspar-nepheline rock also occurs (tinguaite, 35*c*). Between Edda Gijorgis and Abuna Licanos dolerite (22) is met with.

Profile VII.—M-O, Abuna Licanos to Habat Zoddo.

Habat Zoddo (7,500 ft.) consists of dolerite (22). Between this and Abuna Licanos are marked ferruginous breccias (laterite 5), but rock (37), which from its number should be near Edda Exina although it is not marked on Schimper's profile, is a grorudite like that of Semajata.

Profile VIII.—M-P, Abuna Licanos to Amba Berra.

Amba Berra consists of ophitic olivine-dolerite (43 and 22). At the foot occurs a perlitic pitchstone, with porphyritic felspar and green augite, probably intrusive in the dolerite. Between Amba Berra and Abuna Licanos is mainly dolerite (22) and laterite, but at Biet Bendelion occurs a tinguaite almost identical in character with that from the top of Amba Gollo.

DESCRIPTION OF THE ROCK-SPECIMENS.

I. The Grorudites: Paisanite.

The rocks here referred to grorudite occur on Amba Subhat (6), Amba Semajata (14), Amba Berrach (23), Edda Exina (37), and Kedane-Meheret.

The closely-related paisanite (52-54) constitutes Mt. Scholoda, near Adowa.

These rocks are referred to grorudite because they have the characters of hypabyssal rocks, and contain a soda-iron-silicate (ægirine), a potash-soda

Digitized by Google

felspar and quartz. The amount of the ægirine, however, is generally less than in the typical grorudites of Brögger, so that the rocks are rather leucocratic in character, and in some cases may perhaps be referred to the *lindöites* of the same author.[1] In mode of occurrence too, according to the profiles, they differ from the grorudites of the Christiania region, for instead of forming dykes they appear to constitute hummocky-shaped hills, which may be in the nature of laccolites intruded into the phyllites and subsequently exposed by denudation. In colour they are mostly pale pink or brown instead of green, but this is due to the fact that the ægirine is partly, and in some cases wholly, decomposed into ferrite.

They fall under two main types—(1) *Amba Subhat type*, corresponding to the Grusletten type of Brögger; and (2) *Amba Berrach and Semajata type*, corresponding to the Kallerud type of Brögger.

(1) *Amba Subhat type.*

One specimen (6*a*) is a very fine-grained compact pale pink rock, showing no porphyritic crystals, but seen with the lens to be speckled with minute black points (ægirine). Another specimen (6 *b*) has the ægirine arranged in dark green bands, with clearer bands between, so that it presents very much the appearance of a fine-grained gneiss.

These rocks consist of small irregular prismatic ægirines in a base of rectangular felspars, with interspaces filled with clear granular quartz and minute grains of ægirine partly decomposed into ferrite (Fig. 1, Pl. 3).

The prismatic *ægirines* show pleochroism from grass-green (vibration along the length) to brownish yellow (vibration across the length). Most of them give nearly straight extinction, but one showing signs of a cleavage had an extinction angle of about 5°. Compensation with the quartz wedge took place along the length (a axis of indicatrix nearly coincident with crystallographic axis *c*). Of the *felspars*, one or two larger crystals occurred porphyritically. These showed fine twin striations, with symmetrical extinctions in one case as high as 15°. The rectangular felspars of the groundmass are kaolinised; many of the smaller ones are in Carlsbad twins; most of them give a peculiar undulose extinction as if divided into sectors, so that in one part of the rotation between crossed nicols the appearance is that of an hour-glass structure (4 sectors), and in another that of a black cross (8 sectors)—

[1] The "ægirine-granite" from Miask, described by Pirsson (*Am. J. Sci.* IX, 1900, p. 199), though of coarser grain, is a closely related rock.

Digitized by Google

See Fig. 1, Pl. 8.[1] To judge from the chemical composition of the rock these felspars must be referred to anorthoclase. The *quartz* only occurs in the groundmass. The structure is panidiomorphic, with no trace of flow-structure.

A quantitative analysis of this rock gave the following result (I). For comparison under II is given the analysis of a grorudite from Varingskollen, Christiania.[2]

		I.			II.
SiO_2	= ...	73·46	...	...	74·35
Al_2O_3	= ...	12·47	...	...	8·73
Fe_2O_3	= ...	3·64	...	...	5·84
FeO					1·00
CaO	= ...	0·32	...	...	0·45
MnO	= ...	traces	...	...	0·22
MgO					0·07
Na_2O	= ...	5·63	...	...	4·51
K_2O	= ...	4·03	...	...	3·96
Loss on ignition	=	0·44	...	...	0·25
		99·99			99·38

Sp. gr. ... 2·58

A specimen from the hill Kedane Meheret, west of Gossoso, is of a grey, almost colourless rock, which under the microscope presents very similar characters to those of the rocks of Mt. Subhat, with the exception that it contains no porphyritic ægirines. There is a little opacite and ferrite, however, which may represent altered ægirine, and one or two minute green grains in the base are probably of the same mineral. The felspars present the same peculiar extinction in sectors, and granular quartz fills the interspaces. This rock may perhaps be referred to the *quartz-lindöites* of Brögger (*l. c.* p. 133).

(2) *Amba Berrach type.*

Rock (23) from Amba Berrach is pale brown and thickly speckled with small milk-white felspars, giving rectangular and diamond-shaped outlines. It is coarser grained than the Mt. Subhat specimens. Under the microscope idiomorphic rectangular felspars are seen to occupy

[1] This extinction in sectors is precisely similar to that observed by Gränzer in the orthoclase-like mineral occurring in druses in leucite-tephrite from the Eulenberg (*Min Mith.* XI, 1889–90, p. 277, Taf V. figs. 4 and 5). A redetermination of the alkalies in this mineral would be desirable. It may possibly be anorthoclase.

[2] Brögger, *Eruptivgesteine des Kristianiagebietes*, I, p. 48.

Digitized by Google

almost the whole space. Between them is quartz, with short needles of ægirine surrounding the felspars (Fig. 2, Pl. 8). The *felspars* are mostly in Carlsbad twins, and show the same peculiar extinctions as in the case of the Subhat specimens. In many of them (*e.g.* the one on the left of the figure) the hour-glass structure is visible in ordinary light, owing to the fact that one half of the crystal has suffered kaolinisation more than the other. Between crossed nicols the kaolinised sectors show the very fine twin striations characteristic of anorthoclase, while the other two sectors extinguish uniformly. The pale green ægirine needles have th same optical characters as the ægirine of the Subhat specimens.

A pale pink rock (14) from Amba Semajata has the appearance of a very fine-grained granite. The rectangular and square-shaped sections of felspar show the same kind of extinction in sectors as in the preceding, but are in less amount. The interspaces contain mostly lath-shaped felspars, showing some approach to flow structure. Quartz is only sparingly present; opacite and ferrite in grains and patches probably represent altered ægirine. This rock is less acid than those of Mt. Subhat, and shows some approach to the sölvsbergites. In chemical composition, however, it is near to the quartz-lindöites of Brögger.

The result of a partial quantitative analysis of the rock from Amba Semajata is as follows (I). Under II is given for comparison the analysis of grorudite from Kallerud, and under III that of quartz-lindöite from Frön.

		I.		II.		III.
SiO_2	=	68·96	...	71·35	...	69·00
Al_2O_3	=	15·17	...	12·21	...	13·95
Fe_2O_3(+FeO)	=	3·10	...	5·67	...	3·94
CaO	=	0·71	...	—	...	—
MnO, MgO	=	traces	...	—	...	—
Alkalies, &c.	=	(12·06)	...	11·06	...	12·66
		100·00				

A very pale brown almost colourless rock (37) from Edda Exina is very similar to the rock from Amba Semajata, but the rectangular and square felspars are to a large extent replaced by longer lath-shaped felspars.

Paisanite.

The paisanite of Mt. Scholoda is a compact, cream-coloured rock, showing numerous small (up to 2 mm. square) porphyritic crystals of

Digitized by Google

clear quartz and felspar and blueish-black riebeckite. On the weathered surface the crystals of felspar and quartz stand out in high relief.

Under the microscope, porphyritic idiomorphic quartz and felspar crystals are seen to occur in a fine-grained allotriomorphic granular base of quartz and irregular felspars, in parts showing micro-pegmatitic structure (Fig. 8, Pl. 8.)

The porphyritic *felspars* show somewhat rounded outlines, and occur for the most part in groups of two or three individuals: they show lines of parting strongly marked by kaolinisation. No twin striations were observed, but the extinction was mottled and undulose. In cleavage flakes the extinction on *c* was 0°—2°, and on *b* (showing bisectrix nearly normal) 9°—10°. The porphyritic felspars are therefore most probably anorthoclase. The *felspars* of the base show most minute twin striations, and are also to be referred to anorthoclase.

The *quartz* phenocrysts are mostly rounded and embayed by the ground-mass, but some well-defined hexagonal sections, showing positive uniaxial figures, also occur: they contain negative crystals and liquid inclusions with bubbles.

The *riebeckite* is in characteristic moss-like patches, interspersed between the quartz and felspar of the base, and also along the margins of the porphyritic felspars and quartz: it also occurs in larger grains included in the porphyritic felspars. The pleochroism is a=deep indigo-blue, b=deep blue, c=pale brown, as determined in fragments, included in felspars, which showed cleavages. One or two minute grains of ægirine were observed in the slide.

Near the contact with the phyllite the rock becomes very compact, and is almost free from phenocrysts.

A quantitative analysis of the paisanite gave

SiO_2 ...	=	76·01
Al_2O_3 ...	=	11·96
Fe_2O_3 ... FeO ...	=	2·06
CaO ...	=	0·26
MnO ... MgO ...	=	traces
Na_2O ...	=	4·46
K_2O ...	=	4·73
Loss on ignition	=	0·28
		99·76

Sp. gr. ... 2·58

Digitized by Google

II. The Sölvsbergites.

The rocks here referred to sölvsbergite are ægirine-anorthoclase rocks containing either no quartz at all or only a small amount. They occupy as regards basicity an intermediate position between the grorudites containing quartz and the tinguaites containing nepheline. They are for the most part characterised by a trachytic flow structure as opposed to the panidiomorphic structure of the more acid grorudites, the felspars of the groundmass being long lath-shaped instead of short rectangular.[1] They are generally not markedly porphyritic. Owing to the platy arrangement of the felspars the rocks show a peculiar surface shimmer, and are often fissile. In all the above characters they closely resemble the sölvsbergites of the Christiania region described by Brögger.

These rocks occur at Edda Gijorgis (35 c), Amba Bachele (8), Abuna Licanos (29), Abuna Alif (7), Arbaatu Ensesa (18 and 19), Amba Bato (12), Gossoso (13), and Amba Berrach (23).[2]

They may be divided into two groups, viz.—

(1) *The Edda Gijorgis type*, to which also belong the rocks from Amba Bachele and Abuna Licanos.

(2) *Abuna Alif type*, to which belong the rest.

(1) *Edda Gijorgis type.*

This type is somewhat coarser grained than the other, and shows a sub-porphyritic structure with two generations of felspar.

The rock from Edda Gijorgis, which is the material used in the construction of the Obelisks at Axum, is a cream-coloured rock, speckled with greenish black patches of ægirine and small (about 1 mm. square) glassy felspars.

Under the microscope (Fig. 4, Pl. 8) the only minerals observed are felspar and ægirine, with a little opacite. The *felspar* is in two generations, both in large amount. The larger felspars show rectangular sections, and are mostly Carlsbad twins. They consist of anorthoclase, and present precisely the same characters as the porphyritic felspars of the

[1] Brögger remarks in connection with grorudite and sölvsbergite that it is probable that the short rectangular form of the felspars of the groundmass is connected with more acid composition, and the long lath-shaped form with a less amount of silica. (*l. c.* p. 48.)

[2] The ægirine-riebeckite-anorthoclase rock from Akub Teriki, Senafé, described by the author in a previous paper (*Min. Mag.* XII, 95) should without doubt be also referred to the sölvsbergites.

Digitized by Google

paisanite just described, with the same peculiar mottled undulose extinction and well-marked transverse lines of parting. The interspaces between these larger crystals is filled with long lath-shaped felspars of the second generation, showing well-marked flow structure. The *ægirine* occurs in fairly large amount in ragged patches, interpenetrated by the felspar laths. In sections showing a nearly rectangular cleavage, with an optic axis just off the field, the pleochroism was from brownish-yellow to grass-green. In a section showing only one cleavage with nearly straight extinction, and compensating with the quartz wedge along the length, the pleochroism was from brownish-yellow to grass-green with a trace of blue. The pleochroism therefore is—

a = grass-green, with bluish tinge.
b = grass-green.
c = brownish-yellow.

A quantitative analysis of this rock gave the following result (I). For comparison, in II is given the analysis of sölvsbergite from the Lougenthal, Christiania.

		I.		II.
SiO_2	... = ...	68·74	...	62·70
TiO_2	... = ...	trace	...	0·92
Al_2O_3	... = ...	17·86	...	16·40
Fe_2O_3	... = ...	4·27	...	3·84
FeO	... = ...	0·80	...	2·35
MnO	... = ...	0·19	...	trace
CaO	... = ...	0·88	...	0·95
MgO	... = ...	0·10	...	0·79
Na_2O	... = ...	7·23	...	7·13
K_2O	... = ...	5·19	...	5·25
Loss on ignition	= . .	0·88	...	0·70
		100·54		100·58

One specimen (8 *b*) from Amba Bachele presents almost precisely the same characters as those of the Edda Gijorgis rock. It is a cream-coloured rock with a greenish tinge, due to specks of ægirine, and has a marked fissile character. Under the microscope it shows rectangular sections of anorthoclase, with interspaces filled with long lath-shaped felspars and ægirine in small irregular patches. The ægirine is in smaller patches, and the felspars of first generation are somewhat smaller and more lath-shaped than in the preceding rock.

Digitized by Google

A second specimen (8 *a*) from Amba Bachele, however, has a rather different structure, more akin to that of the grorudites.

This is a pale gray, somewhat cavernous rock, showing to the lens small porphyritic white felspars and black specks of ægirine. Under the microscope it is seen to consist of rectangular anorthoclases, similar to those in the preceding rock, and short prismatic crystals of ægirine, with the interspaces filled with an altered unindividualised felsitic-looking base instead of the long lath-shaped felspars of the preceding rock.

Rock (29), from Abuna Licanos, is a cream-coloured rock consisting of tabular felspars with black specks of ægirine and brown patches of an altered mineral. Under the microscope it is seen to be rather more coarse-grained and less porphyritic than the rock from Edda Gijorgis. The felspars of the first generation present the same characters, but are larger, as are also those of the second generation, which are rectangular rather than long lath-shaped. The ægirine is in rather more definite prismatic crystals.

(2) *Abuna Alif type.*

The rock (7) from Abuna Alif is, like the preceding, of a pale cream colour, with small black specks of ægirine, but is more compact and finer grained. It has a scaly appearance, and is markedly fissile, owing to the tabular arrangement of the felspars. It consists of a felt of lath-shaped felspars with trachytic flow structure, and ægirine in irregular prismatic fragments, interspersed between the felspar laths. Some granular epidote is present, due to the decomposition of the felspars.

From Arbaatu Ensesa there are two specimens.

One (18) is a deep reddish brown compact platy rock with greasy lustre, which under the microscope shows a similar structure to that of the preceding, except that the felspar mesh is finer-grained and the ægirine is in smaller amount: there is, however, much opacite and ferrite which gives the colour to the rock, and is the result probably of the decomposition of ægirine.

The other specimen (19) from Arbaatu Ensesa is coarser-grained and more like the Abuna Alif rock. It is, however, much decomposed, and no unaltered ægirine is seen in the section. This is also the case with the specimens from Amba Berrach (21), Gossoso (13), Amba Bató (12), and Amba Hedscha (20).

III. The Tinguaites.

These rocks contain, besides felspar and ægirine, also nepheline, and in some cases a certain amount of riebeckite accompanying the ægirine.

Digitized by Google

They occur between Abuna Licanos and Amba Gollo, at the top of Amba Gollo (35), and at Biet Bendelion (39) between Abuna Licanos and Amba Berra, and also on Edda Gijorgis (35*b*).

Though characterised by the same mineral constituents, they present different varieties of structure.

(1) *Tinguaite* between Abuna Licanos and Amba Gollo.

This is a rock with a peculiar mottled appearance, due to green patches of ægirine in a spotted colourless to pink groundmass.

Under the microscope are seen (Fig. 6, Pl. 3) ragged ophitic patches of ægirine, with a little moss-like riebeckite in a base of minute felspar microliths, showing marked flow structure. Scattered through the base, not standing out very prominently as porphyritic crystals, but looking as though they had separated almost at the same time as the felspar microliths, are numerous fairly large rectangular and hexagonal sections of nepheline, often congregated into groups surrounded by the ægyrine patches which radiate out from them. These nephelines are crowded with felspar microliths, like those of the base, arranged in a circular way in a sort of whirl.

(2) *Tinguaite* from top of Amba Gollo, and from Biet Bendelion.

The rock (35) from the top of Amba Gollo shows a clear white ground, through which are disseminated round patches consisting of a central brown part of altered nepheline, surrounded by dark green ægirine. Under the microscope the constituents are seen (Fig. 5, Pl. 3) to be the same as in the preceding, but the structure of the base is allotriomorphic granular instead of trachytic. The nepheline also occurs only in large irregular porphyritic crystals, surrounded by patches of grass-green ægirine with long projecting rays. The riebeckite is in larger amount in ophitic patches and moss-like aggregates, often showing, however, regular prismatic outlines with pleochroism a (along the length), deep indigo blue; c (across the length), pale brownish yellow; and with straight extinction and compensation with quartz wedge along the length.

The base showed only here and there lath-shaped felspar microliths, with flow structure, but consisted apparently mainly of interlocking felspars, showing no twin lamellæ: nepheline probably is also present.

The rock (39) from Biet Endelion showed almost precisely the same characters, except that the large nephelines were wholly decomposed.

(3) *Tinguaite* from Edda Gijorgis.

This rock (35 *b*) was of a different character to the preceding tinguaites. It is a greenish grey rock, with greasy lustre like a phonolite, and

Digitized by Google

shows to the naked eye no porphyritic crystals of nepheline or patches of ægirine, but only minute black specks of the latter mineral.

Under the microscope small, rather pale green to yellow ægirines, in short prisms, are seen very uniformly distributed in a base of irregular interlocking felspars and much clear nepheline in small rectangular sections, some of them with inclusions of minute felspar microliths as in the tinguaite (1). In parts of this slide the felspars are lath-shaped, and show well-marked trachytic flow-structure with the nephelines wedged in between the laths. Some epidote is present. One or two larger porphyritic felspars much corroded also occur.

A quantitative analysis of this rock gave the following result (I). Under II, for comparison, is given the analysis of a tinguaite from Hedrum :—

				I.		II.
SiO_2	...	=	...	57·81	...	56·58
Al_2O_3	...	=	...	18·74	...	19·89
Fe_2O_3	...	=	...	5·76	...	3·18
FeO	...	=	...	0·42	...	0·56
MnO	...	=	...	traces	...	0·47
CaO	...	=	...	1·28	...	1·10
MgO	...	=	...	traces	...	0·13
Na_2O	...	=	...	9·35	...	10·72
K_2O	...	=	...	4·52	...	5·43
Loss on ignition		=	...	1·50	...	1·77
Sp. gr. ...		...	2·64	99·38		99·83

The so-called nepheline-tephrite, from the valley of the Jamma, in Schoa, described by Michel Levy (C.R. CII, 1886, p. 451) appears to be a tinguaite, with characters very similar to those of the above rocks. It occurs in thick dykes in Jurassic rocks, and consists of nepheline and small microliths of felspar which Michel Levy refers to oligoclase, one or two porphyritic orthoclases and a green pleochroic "amphibole" (ægirine ?) in patches visible to the naked eye with long radiations.

Phonolites from Mt. Kenya and also from Teneriffe and Gran Canaria show close resemblances to the above tinguaites in containing ragged ægirine patches surrounding nepheline phenocrysts.

Some of the so-called "nepheline-syenite" (tinguaite) dykes in Pocos de Caldas, Brazil, described by J. Machado (*Min. Mitth.* IX, 1888, p. 337), present very similar characters to the tinguaite (3), *e.g.* the one represented in Fig. 6, Pl. V, and Figs. 3 and 4, Pl. VI (*loc. cit.*), the

Digitized by Google

pleochroic grass-green "augite," with its low angle of extinction, being most probably ægirine.

IV. The Trachyte and Pitchstone.

Trachyte (15), from the top of Amba Hedscha (9,200 feet).

This is a pale purplish trachytic-looking rock, showing small phenocrysts of anorthoclase. It is very similar in character to the riebeckite-anorthoclase-trachyte from Mt. Kishyat, described by the author (*Min. Mag.* 1899, XII, 94).

Under the microscope phenocrysts of anorthoclase, showing the characteristic fine twin striations, occur in groups in a trachytic base of small felspar laths, with flow structure. There is much opacite, which might very well represent altered riebeckite, as in the rock from Kishyat.

Pitchstone (42), from foot of Amba Berra.

This rock shows in a thin section a pale-brown perlitic glass crowded with minute felspar microliths (with a low power only visible between crossed nicols). It contains a few small phenocrysts of felspar, and one or two long prisms of pale-green augite, with extinction which in the two or three sections examined did not exceed 17°, and with pleochroism along the length, pale yellow green, and across the length yellow.

A quantitative analysis gave the following result (I). In II is given the composition of the anhydrous rock after deducting the loss on ignition, in order to show what relation it bears to the grorudites.

		I.		II.
SiO_2	=	67·03		71·13
Al_2O_3	=	14·25		15·12
Fe_2O_3	=	1·96		2·08
FeO	=	1·70		1·81
MnO	=	trace		—
CaO	=	1·05		1·12
MgO	=	trace		—
K_2O	=	3·90		4·13
Na_2O	=	3·85		4·08
Loss on ignition	=	5·73		—
		99·47		99·47

Sp. gr. ... 2·376

Digitized by Google

V. The Dolerites and Basalts.

The *dolerites* occur at Dăbra Sina, Ganef, and the top of Amba Berra. The rock (24) from the top of Dăbra Sina is a coarse-grained aggregate of purple titaniferous augite, and much clear unaltered olivine, with long prismatic felspars, and magnetite in grains and long rods. There is a slight approach to ophitic structure.

The dolerite from Ganef is similar, but here the ophitic structure is more pronounced: olivine is in large amount, but in smaller grains: some of the felspars show undulose extinction, and are probably less basic than the others.

The rock (48) from the top of Amba Berra is similar, but somewhat finer grained.

The *basalts* occur at Amba Herres (17), Magdalai (16), and also between Edda Jasus and Abuna Licanos (26). The first two have apparently the characters of old rocks, and the last of a glassy more recent lava.

The rock (17) from Amba Herres is non-porphyritic, and shows in section a fine-grained aggregate of felspar laths, augite and magnetite: in the section is seen a large irregular foreign quartz fragment, surrounded by the usual zone of alteration of pale green augite needles.

The rock (16) from Magdalai is also non-porphyritic. It is very fine-grained, and shows felspar laths and large magnetite grains, with augite converted into viridite: some calcite and epidote are also present.

The basalt (26) from near Edda Jasus is of a different character. It consists of sharply defined, small lath-shaped felspars, and some altered olivines in a dense glassy base.

CONCLUSIONS AND COMPARISON WITH ROCKS FROM OTHER PARTS OF AFRICA.

These rocks of Abyssinia, just as their counterparts in the Christiania Grorudite-Tinguaite District, offer a striking example of a "rock series" as defined by Brögger. Thus they belong to a number of types which, as regards mineral and chemical composition, possess certain relations in common, while in other respects they exhibit a continuous change of composition from one end of the series to the other. They are referred to the grorudite, sölvsbergite, tinguaite series, since they are hypabyssal rocks, characterised (1) mineralogically, by a potash-soda felspar (anorthoclase), a soda-iron silicate (ægirine and riebeckite[1]), with, in the more acid

[1] Brögger's cataphorite was not observed in these Abyssinian rocks.

Digitized by Google

members quartz, and in the more basic nepheline; and (2) chemically, by their low percentage of lime and magnesia, and their high contents of alkalies with soda in excess of potash.

According to Dr. Schimper's profiles they have been intruded through the phyllites and schists belonging to the basement rocks of Abyssinia (the metamorphic group of Blanford), and now form hummocky-shaped hills. This certainly appears to be the case with the paisanite of Mt. Scholoda, of which many specimens were collected on both sides of the mountain. In the case however of some of the other rocks, further observations in the field may possibly show that they do not constitute the main bulk of a mountain, as shown in the profiles, but occur as dykes traversing other rocks.

The magma from which they were differentiated must have been one rich in soda, and was in all probability a nepheline-syenite. The mineral character of the granite of the Mărab, which is the only coarse-grained plutonic rock in Dr. Schimper's collection, is not suggestive of its being the source of these rocks.

With regard to their geological age nothing definite can be said. The rocks, however, are mineralogically and chemically closely related to volcanic rocks in other parts of Africa which are referred to the Tertiary period. The resemblance between the above tinguaites and the phonolites of Mt. Kenya and of Teneriffe and Gran Canaria has already been remarked upon (p. 269). Anorthoclase is the prevailing felspar in the rocks both of Kenya and Kilimandjaro, and Rosiwal[1] has described phonolitic and trachytic rocks containing the same felspar in the S. of Abyssinia (Schoa).

This line of soda-rich volcanic rocks can be traced further south into Madagascar, where eruptions have taken place as in Abyssinia through the crystalline schists which form the basement rocks of the island. Amongst some rock specimens brought back by Dr. Forsyth Major from Sirabe, Madagascar, are trachytes presenting very similar characters to the riebeckite-trachytes of Senafe, and to the trachyte from Amba Hedscha (p. 270), in which the iron silicate, however, has been altered to opacite. Trachytes from Madagascar, in the Museum of Practical Geology, Jermyn Street, which, through the kindness of Mr. Teall, I have had the opportunity of examining, also contain porphyritic felspars showing the minute twin striations characteristic of anorthoclase.

---

[1] *Beitr. Geol. Kennt d. Öst. Afrika*, 74 and 81, 1891.

Digitized by Google

The prevalence of volcanic rocks, rich in soda, would almost seem to be a characteristic feature of the African continent and its adjacent islands.[1]

EXPLANATION OF PLATE 3.

Microsections of rocks from Abyssinia.

Fig. 1.—Grorudite from Amba Subhat.

Grass-green ægirine and rectangular felspars in a quartz base containing minute grains of ægirine. Some of the felspars are represented as seen between crossed nicols, and show the extinction in sectors.

Magnification, 70 diam. ¼ inch objective.

Fig. 2.—Grorudite from Amba Berrach.

Rectangular felspars showing hour-glass extinction and fringed with minute needles of ægirine in a quartz base.

Magnification, 30 diam. ½ inch objective.

Fig. 3.—Paisanite from Mt. Scholoda.

Phenocrysts of anorthoclase and quartz (top of figure) with moss-like riebeckite in a granular quartz-felspar base.

Magnification, 10 diam. 1¼ inch objective.

Fig. 4.—Sölvsbergite from Edda Gijorgis.

Phenocrysts of anorthoclase in a trachytic base of felspar laths and ragged grass-green ægirine.

Magnification, 17 diam. 1 inch objective.

Fig. 5.—Tinguaite from Amba Gollo.

In the centre is a large irregular phenocryst of nepheline surrounded by ægirine which radiates out from it. Above and below is more radiating ægyrine, and to the right and left moss-like riebeckite.

Magnification, 10 diam. 1¼ inch objective.

Fig. 6.—Tinguaite from between Abuna Licanos and Amba Gollo.

Ragged patches of ægirine and hexagonal and rectangular sections of nepheline with a little riebeckite (centre of figure) in a base of minute felspar microliths showing flow structure.

Magnification, 10 diam. 1½ inch objective.

[1] Lacroix (*Comptes Rendus*, CXXVIII, 1467) has recently described rhyolites from Somali-land containing ægirine and riebeckite.

Digitized by Google

On Stokesite, a new mineral containing tin, from Cornwall.

By A. Hutchinson, M.A.,

Demonstrator of Mineralogy in the University of Cambridge.

[Read November 14th, 1899.]

WHILE engaged last summer in arranging the Carne collection of minerals acquired for the Cambridge Mineralogical Museum in the early part of 1899, my attention was attracted by a single, colourless, transparent crystal, about 10 mm. long, implanted in a shallow cavity on a specimen of crystallised axinite from the St. Just district of Cornwall. In general appearance the crystal resembled somewhat closely one of selenite of the ordinary habit, and indeed was entered as gypsum in the catalogue of the Carne collection. The unusual nature of the occurrence led me to make as complete a crystallographic and chemical examination as the limited amount of material at my disposal would allow. The results obtained have established the existence of a new mineral species for which, in a preliminary communication,[1] the name Stokesite was proposed, in honour of Sir George Gabriel Stokes, Bart., Lucasian Professor of Mathematics in the University of Cambridge. I am now able to lay before the Society a detailed account of the measurements and experiments which have been made.

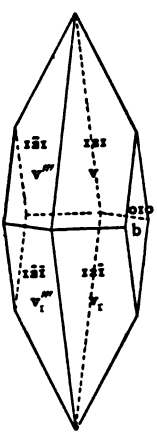


Fig. 1.

1. *Crystallographic characters.*

System: Prismatic (bipyramidal or holohedral class):—

$$a : b : c = \cdot 8463 : 1 : \cdot 8033.$$

Forms present: $b(010)$, $v(121)$, both largely developed; $c(001)$, $s(565)$ and $t(122)$, all three very small. Faces of the form $m(110)$ can be produced by cleavage.

[1] *Phil. Mag.* 1899, Series V, XLVIII, 480.

Digitized by Google

TABLE OF ANGLES.

Angle.	Calculated.	Observed Mean.	Limits.	Edges.
121 : $\bar{1}21$ *vv'*	101°38′	101°38′	100°11′—101°59′	4
121 : $\bar{1}\bar{2}1$ *vv''*	—	141 0*	140 36—141 2	4
121 : $1\bar{2}1$ *vv'''*	64 54	64 52	64 37— 65 9	4
121 : $12\dot{\bar{1}}$ *vv,*	39 0	38 57	38 32— 39 24	4
010 : 121 *bv*	—	57 33*	56 40— 58 1	8
010 : 110 *bm*	70 54	70 32	70 50— 70 14	2
010 : 565 *bs*	69 7	68 55	68 52— 68 58	2
110 : 121 *mv*	24 48	24 49	——	1
110 : $1\bar{2}1$ *mv'''*	56 10	56 45	——	1
121 : 122 *vt*	15 48	16 17	——	1

The axial ratios have been calculated from the mean values obtained for the two angles *vv''* and *bv*. The habit of the crystal is shown in the figure. It was regularly developed and nearly complete, being attached to the wall of the small depression in which it was found by a crystal of axinite, which penetrated it. The basal pinakoid *c* was developed as a small rough face at one end of the crystal only; the plane *t* was also observed but once, and lay between *c* and one of the faces of the form *v*. The form *s* was represented by two very narrow planes lying on the edge *vv'''*. These faces were not sufficiently bright to enable their angular positions to be determined with much accuracy. Fair reflections were obtained from the eight faces of the bipyramid *v*, and from the two faces of the brachy-pinakoid *b*. Some of these planes were, however, rather rounded, and the elements given above cannot be regarded as more than moderate approximations to the truth, and will doubtless require modification when further material is available for examination.[1] The crystal has been so placed as to enable the cleavage faces *m* to be taken as belonging to the prism 110. The bipyramid *v* may then receive the indices 121.

2. *Physical Characters.*

Cleavage: *m* perfect; *b* less so. Fracture conchoidal. Brittle. Hardness about 6. Specific gravity, 3·185 at 22·9°C (determined by suspending a small fragment in methylene iodide diluted with benzol). Lustre vitreous, pearly on *b*. Transparent, colourless; streak white.

[1] Some of the numerical values here stated differ slightly from those given in the *Philosophical Magazine*. The numbers now adopted are the final results of a careful re-calculation.

Digitized by Google

Special Optical Characters.

The plane of the optic axes is parallel to $b\{010\}$; the acute bisectrix is perpendicular to $c\{001\}$.

As the amount of material available did not allow of the preparation of any sections, the angle between the optic axes was measured when the crystal was immersed in a liquid whose index of refraction was approximately equal to the mean principal index of the crystal. For this purpose quinoline, $\mu=1{\cdot}616$ at 22°C. (sodium light), was found suitable, the border between a crystal fragment and the liquid being examined under the microscope.

For sodium light $2V=69\frac{1}{2}°$ approximately; for thallium light the value is about 20′ greater, hence $\rho < v$ and $2E=134°$.

The crystal is optically positive, and the principal index, γ, of a ray vibrating parallel to the acute bisectrix, can be determined by using as prisms, pairs of faces of the form $v\{121\}$ such as 121 and $1\bar{2}1$. Measurements were made for two pairs of faces, and the angle of minimum deviation D was found to have a mean value of 26°25′. The prism-angle $A=39°$. We have therefore—

$$\gamma=\frac{\sin\frac{1}{2}(39°+26°25')}{\sin 19°30'}=1{\cdot}619 \text{ (sodium light).}$$

These prisms give also a second refracted image, due to the wave-velocity p, which is connected with the two principal wave-velocities a and b by the equation $p^2=a^2\sin^2\theta+b^2\cos^2\theta$, where θ is the angle between the normal to the plane bisecting the refracting angle of the prism and the minor axis of the ellipse ab.

Since γ and $2V$ are known, we can now calculate the two principal indices α and β from the equations—

$$\text{(i)}\quad p^2=a^2\sin^2\theta+b^2\cos^2\theta.$$

$$\text{(ii)}\quad \tan V=\sqrt{\frac{a^2-b^2}{b^2-c^2}}$$

$$\text{(iii)}\quad c^2=\frac{1}{\gamma^2}.$$

In (i) we have $\theta=34°42'$, $\sin^2\theta=\cdot3241$ and $\cos^2\theta=\cdot6759$. The deviation of the extraordinary ray D' was found to be 26°5′, and the prism angle $A=39°$.

Hence from the formula $\mu=\dfrac{\sin\frac{1}{2}(A+D')}{\sin\frac{1}{2}A}$ we get $\dfrac{1}{p}=1{\cdot}6114$ and

Digitized by Google

If now in (ii) we substitute for c^2 its numerical value ·3815, we have—

$$\text{(i)} \quad \cdot 3851 = \cdot 3241\ a^2 + \cdot 6759\ b^2$$
$$\text{(ii)} \quad \cdot 4818\ (b^2 - \cdot 3815) = a^2 - b^2$$

$$\text{Hence} \quad \alpha = 1 \div a = 1 \cdot 609$$
$$\beta = 1 \div b = 1 \cdot 6125$$
$$\text{and} \quad \gamma = 1 \div c = 1 \cdot 619$$

8. *Chemical Composition.*

As the crystallographic and optical characters failed to lead to the identification of the mineral, it was resolved to sacrifice a portion of the crystal for chemical analysis. A preliminary examination of a few minute fragments showed that the substance was insoluble in concentrated hydrochloric acid, and infusible before the blowpipe, to whose flame it imparted no colour. Heated in a microcosmic salt bead it gave a skeleton of silica. For the purposes of a combined qualitative and quantitative analysis, ·1128 gram, placed in a platinum boat, was heated to dull redness in a current of dry air in a glass tube. Water was deposited on the tube, and the boat lost ·0097 gram. That the loss of weight of the substance was entirely due to the expulsion of water was proved by collecting the latter in a small weighed tube containing sulphuric acid.

The contents of the platinum boat were next transferred to a platinum crucible and heated to bright redness; as no further change of weight took place, sodium carbonate was added, and the substance fused till decomposition was complete. The fused mass was brought into solution in hydrochloric acid, and the silica separated by evaporation to dryness in the ordinary way. The crucible in which the fusion was conducted was found to have undergone no change of weight.

The solution from which the silica had been separated was next treated with hydrogen sulphide, when quite unexpectedly a yellow precipitate began to form. This was filtered off and found to possess the properties of tin disulphide. It was converted into oxide and weighed. From the oxide the metal was obtained by reducing with potassium cyanide, and proved to be tin by the ordinary tests.

The solution from which the tin had been removed was treated with nitric acid, ammonium chloride and ammonia, and a small precipitate of ferric hydroxide obtained. On proceeding with the analysis, calcium was found to be present. It was precipitated as oxalate, and weighed as oxide. The latter proved on spectroscopic examination to be free from

Digitized by Google

barium and strontium. Magnesium could not be detected, nor could any potassium be found in the residue. As the glass tube in which the substance was originally heated showed no trace of etching, fluorine was judged to be probably absent, and a small fragment of the crystal tested for boron gave a negative result.

The results of this analysis are stated in column I of the table below; and as will be seen from the numbers there given, no less than 27 per cent. of the substance was left unaccounted for.

It seemed at the time possible that this deficiency was due to the presence of sodium, which could not be estimated in the first analysis, and it was therefore considered advisable to sacrifice another portion of the crystal for a second determination.

For this purpose ·1111 gram was heated to expel water, and then distilled with pure aqueous solution of hydrofluoric acid in a platinum apparatus constructed by Messrs. Johnson and Matthey, according to the designs given by Prof. Story-Maskelyne,[1] whose instructions were carefully followed in every detail. The silica was weighed as potassium silicofluoride, and no tin could be detected in the distillate.

The apparatus, which appeared to be quite tight at the beginning of the experiment, leaked a little towards the end, and a loss of silica occurred, which, though slight in itself, was sufficient to make a serious difference in the percentage found, owing to the very small amount of material available for analysis. On bringing the contents of the platinum still into solution, and passing in hydrogen sulphide, it was at once remarked that the precipitate of tin disulphide was much larger than that obtained in the first analysis, and when converted into oxide was found to amount to 33·3 per cent. The quantity of iron obtained in this analysis was quite insignificant, the calcium oxide agreed well with that obtained before, and only a little sodium could be detected in the residue.

The numerical data are as follows:—

	Analysis I.	Analysis II.
Weight of substance taken ...	·1128	·1111
,, H_2O expelled	·0097	·0095
,, SiO_2 obtained	·0486	—
,, K_2SiF_6 ,, ...	—	·1606
,, SnO_2 ,, ...	·0066	·0370
,, CaO ,, ...	·0152	·0149
,, Fe_2O_3 ,, ...	·0021	·0008
,, Na_2SO_4 ,, ...	—	·0032

[1] *Phil. Trans. Roy. Soc.* 1870, CLX, 191.

Digitized by Google

These numbers lead to the percentages given in columns I and II respectively.

	I.	II.	III.	IV.	V.
SiO_2	48·1	89·4	48·1 ÷ 60 = ·72		42·65
SnO_2	5·85	33·3	33·3 ÷ 150 = ·22		35·55
CaO	18·5	18·4	18·45 ÷ 56 = ·24		18·27
H_2O	8·6	8·55	8·6 ÷ 18 = ·48		8·53
Fe_2O_3	1·9	·7	—		—
Na_2O	—	1·3	—		—
	72·95	96·65	98·45		100·00
Loss	27·05	3·35			

On looking at the results given above under columns I and II it will be seen that the determinations of water and calcium oxide agree closely. There can be no doubt that of the two silica estimations, that under I is the most trustworthy; the analysis proceeded perfectly smoothly, and the result may be accepted with confidence. On the other hand, the first tin determination has no quantitative value, for the solution containing it was evaporated several times with hydrochloric acid to ensure the separation of the silica, and, as is well known, stannic chloride is volatile under these conditions; moreover, the actual mass present being so small, a comparatively insignificant loss of material is sufficient to wholly vitiate the result. The major part of the iron, if not indeed the whole of it, I am inclined to attribute to external impurity, for the air of the mineralogical laboratory is unfortunately liable to be contaminated with the dust from rusty iron to a quite exceptional extent. It is not easy to decide whether in the circumstances the small amount of sodium obtained is to be considered an essential constituent of the mineral or not.

If, as seems permissible, we accept the numbers given in column III as representing correctly the percentage composition of the mineral, and from them attempt to calculate a formula, we obtain for the atomic ratios the values in column IV, and from these we see that

$$CaO : SnO_2 : SiO_2 : H_2O = 1 : 1 : 3 : 2$$

—very nearly. The formula is therefore $CaO,SnO_2,3SiO_2,2H_2O$.

The percentage composition corresponding to this formula is given in column V, and on comparing the theoretical numbers with the analytical results we find satisfactory agreement in the case of the calcium oxide, the water and the silica, the quantity of stannic oxide being alone deficient. The composition can only finally be settled when more

Digitized by Google

material is available and new analyses can be made on larger quantities, but for the present we are, I believe, justified in assigning to stokesite the empirical formula $H_4CaSnSi_3O_{11}$.

Minerals containing stannic oxide and silica have been described by Breithaupt,[1] Bischof,[2] Tschermak,[3] and Collins.[4] The material analysed by these authors was massive, and its homogeneity open to doubt. Stokesite appears therefore to be the first example of a well crystallised definite compound containing silica and stannic oxide as essential constituents.

When we come to consider the constitution of this mineral, we see that several views may be held, the choice between many possible formulæ depending on the part assigned to the tin and to the hydrogen. Analogy may help us here, for catapleiite, a mineral of similar chemical composition, $H_4Na_2ZrSi_3O_{11}$, has been variously regarded; viz. as a hydrated meta-silicate $Na_2Zr(SiO_3)_3.2H_2O$ by Rammelsberg;[5] as a basic meta-silicate $H_2Na_2[Zr(OH)_2][SiO_3]_3$ by Brögger;[6] as a compound of an ortho- and meta-silicate $Na_2SiO_3.H_4Zr(SiO_4)_2$ by Dana;[7] and lastly as an acid salt of a tetrasilicic acid $H_4Na_2(Si,Zr)_4O_{11}$ by Groth.[8] According to the first three of these authors the zirconium is regarded as a base; whilst by Groth it is taken to replace silicon. Again, while Rammelsberg regards the water as water of crystallisation, the other authors look upon the hydrogen as part of the acid. Exactly similar formulæ may be written for stokesite when Zr is replaced by Sn, and Na_2 by Ca; and if the zirconium in catapleiite is playing the part of a metal, we have an equal right to assign the same part to tin in stokesite. If the hydrogen is present as water of crystallisation, we must either adopt the meta-silicate formula, and regard the tin as metallic in function, or else look upon the compound as a derivative of a tetrasilicic acid, and write the formula thus: $Ca(SiSn)_4O_9.2H_2O$—a less plausible hypothesis.

In order to obtain, if possible, a clue to the most probable formula, a determination was made of the water driven off at different temperatures from the second portion of material analysed. The mineral remained

---

[1] Breithaupt, *Pogg. Ann.* 1846, LXIX, 435.

[2] Bischof, *Jahrbuch f. Mineralogie*, 1854, 346; 1855, 841.

[3] Tschermak, *Sitz. Ber. d. k. Ak. d. Wiss.* Wien, 1864, XLIX (i), 330.

[4] Collins, *Min. Mag.* 1882, IV, 8, 109, 115.

[5] Rammelsberg, *Mineralchemie*, 2nd Suppl. 1895, p. 450.

[6] Brögger, *Zeits. f. Kryst.* 1890, XVI, 458.

[7] Dana, *Mineralogy*, 1892, p. 413.

[8] Groth, *Uebersicht der Mineralien*, 1898, p. 159.

Digitized by Google

unchanged at 100° C., heated to 220° C. it lost 1·9 per cent., at 350° C. the loss amounted to 6 per cent., and the rest of the water was given off between 350° C. and dull redness. From these numbers we may conclude that the water is not all present as water of crystallisation. The behaviour of catapleiite is strikingly similar,[1] and apophyllite, according to Hersch,[2] does much the same. In the latter case some of the hydrogen is believed to be present as water of crystallisation, the rest as acid hydrogen; and on looking at stokesite from this point of view we can regard it as an acid meta-disilicate, $H_2(Sn,Si)_2O_5,Ca(SnSi)_2O_5,H_2O$, or as $H_2CaSnSi_3O_{10}.H_2O$, a derivative of trisilicic acid. Lastly, if we conclude from the results above that no water of crystallisation is present, we may represent it either as a compound of a disilicate and an ortho-silicate, $H_4CaSi_2O_7,SnSiO_4$; or as $H_4Ca(SnSi)_4O_{11}$, a salt of a tetrasilicic acid; the latter view having perhaps the most to recommend it.

5. *Locality.*

The specimen is described in the catalogue of the Carne Collection as from Roscommon Cliff, St. Just. This cliff descends somewhat abruptly into the sea very nearly due west of Trewellard. On a hurried visit to the neighbourhood I was shown axinite *in situ* in several places on the cliffs, especially at "The Crowns," at Botallack Head, and near the bottom of Roscommon Cliff. A comparison of the matrix of stokesite with the axinite specimens from this district leaves no room for doubting that the locality given in the catalogue is correct.

A careful examination of the axinites in the collection at the British Museum and in the museums at Penzance, Camborne, Redruth and Truro, has unfortunately failed to bring to light any more specimens of this interesting mineral.

---

[1] Brögger, *loc. cit.*, p. 457, found that catapleiite lost 1·66 per cent. at 220° C. and 7·1 per cent. at 270° C. out of a total percentage of 9·25.

[2] Hersch, *Inaug. Diss.*, Zürich, 1887, 26.

Digitized by Google

Sulpharsenites of Lead from the Binnenthal.

By R. H. Solly, M.A.

With Analyses by H. Jackson, B.A., B.Sc.

[Read Nov. 14th, 1899.]

Part I.

General Description and Chemical Analyses, with a Crystallographic Account of Jordanite. [Plates IV, V].

Historical and Introductory.

THE metallic grey minerals which are found in the white saccharoidal dolomite of the Binnenthal have been known ever since the old priest Walpen of Binn and R. von Ritz began collecting them nearly seventy years ago.

The name "binnite" was first given indiscriminately to the grey metallic minerals; afterwards these were subdivided into "Kugel Binnit" and "Stangen Binnit."

The first division, "Kugel Binnit" (so called from its pea-shaped form), is tennantite, locally known as "Kupfer Binnit." The second division, "Stangen Binnit" (so called from its rod-shaped form), comprises the minerals sartorite, rathite, dufrenoysite and jordanite.

Lardy,[1] in 1833, is the first to notice in print the occurrence of these minerals, and specimens from the Binnenthal at that time were usually labelled "Grey Copper from St. Gotthardt."

In 1839 and 1840 Wiser[2] published the results of some qualitative analyses of these minerals in which he found Pb,S,Sb,As,Cu,Ag. The antimony is noteworthy on account of its great rarity, as will be seen later.

In 1845 Damour[3] analysed two specimens of "Stangen Binnit"; his crystallographic description, however, refers to a crystal of "Kugel Binnit." To this combination he gave the name dufrenoysite. The

[1] *Denksch. Schweiz. Ges.* 1833, Bd. I, Abth. 2, p. 244.

[2] Leonhard's *Neues Jahrb. für Min.* 1839, pp. 414, 559; 1840, p. 217.

[3] *Ann. Chim. Phys.* 3rd Series, XIV, p. 379.

Digitized by Google

analysis seems to have been made upon fairly pure specimens of dufrenoysite (see Table of Analyses, Nos. 27, 28).

In 1855-7 von Waltershausen, Des Cloizeaux, Marignac and Heusser published their researches on this group; v. Waltershausen[1] pointed out Damour's mistake mentioned above, but he himself curiously made a similar mistake, describing and drawing a characteristic crystal of dufrenoysite, and combining it with Uhrlaub's three analyses of impure sartorite crystals (Nos. 4, 8, 10); to this combination he gave the name arsenomelane. Heusser[2] described and drew a typical crystal of sartorite with its characteristic dome planes, but added to the confusion of names by calling it binnite.

Des Cloizeaux and Marignac[3] visited the Binnenthal, and brought back a number of crystals of jordanite and sartorite.

Des Cloizeaux combined their measurements of crystals of jordanite and sartorite, and calculated a set of crystallographic elements, calling the mineral dufrenoysite. They figured three typical crystals of jordanite and two of sartorite. If Des Cloizeaux had taken the densities of each, or examined the streak, he would have separated his crystals, as the density of jordanite is 6·45, while that of sartorite is 4·98; and the streak of jordanite is black, while that of sartorite is reddish-brown.

In 1857 Uhrlaub and Nason[4] each undertook two analyses on material sent to them by v. Waltershausen. (Nos. 17, 18, 19, 20.)

A little later Stockar-Escher[5] published four analyses made on impure sartorite or rathite. (Nos. 6, 7, 9, 22.)

In 1862 vom Rath[6] began a thorough investigation of this group, and published in 1864 the first full account.

He divided the sulpharsenites of lead into three species :—

Scleroclase (or Sartorite of Dana).
Dufrenoysite.
Jordanite.

Reference to this work will be made under the description of each species.

---

[1] *Pogg. Ann.* 1855, XCIV, 115.
[2] *Pogg. Ann.* 1856, XCVII, 120.
[3] *Ann. Mines*, 1855, Ser. 5, VIII, 389.
[4] *Pogg. Ann.* 1857, C, 540.
[5] Kenngott, *Uebersicht*, 1859, for 1856–7, 176.
[6] *Pogg. Ann.* 1864, CXXII, 371.

Digitized by Google

In 1864 Berendes[1] gave two analyses of dufrenoysite (Nos. 21, 28).

In 1866 T. Petersen[2] published two analyses (Nos. 15, 16) without any crystallographic account. One analysis agrees with Mr. Jackson's new analysis of rathite.

In 1878 vom Rath[3] described some more crystals of jordanite, and had an analysis made in Prof. Ludwig's laboratory by Sipőcz[4] of some of these crystals, giving a formula $4PbS.As_2S_3$, with S.G. 6·384 and 6·401 (Nos. 32, 33).

In the same year Tschermak[5] described some crystals of jordanite from Nagyág, and had some of the material analysed by Ludwig,[6] which agreed with Sipőcz's determination, except that he found 1·87 per cent. of Sb. (No. 34.)

In 1877 Lewis[7] described a crystal of jordanite, in the British Museum, associated with a crystal of binnite on a crystal of blende. He notified 5 new forms, but added that of these (025) was not determined, and gave no measurements for (225). (052 and 252 of Baumhauer.)

In 1891 Baumhauer[8] published two papers on jordanite, removing it from the rhombic system to the oblique. It will be seen under the description of jordanite that I have confirmed this alteration.

In 1894 Baumhauer[9] described a new twin law of jordanite, viz. twin plane $(\bar{3}01)$ (printed by mistake $\bar{1}03$). In the same volume (p. 87) he describes a large crystal of dufrenoysite, with an analysis by König (No. 24).

In 1895 Baumhauer[10] published a long paper on sartorite, giving a number of new forms, and an analysis by König (No. 5).

In 1896 Baumhauer[11] added a new mineral to this group, which he called rathite, and gave an analysis of it by Bömer (No. 14).

In 1897 Baumhauer[12] added to our knowledge of the rare mineral dufrenoysite by measurements of three fine crystals with new forms.

---

[1] *Inaug. dissert.* Bonn, 1864.
[2] *Ber. Offenb. Ver.* 1866, VII, 128. *Jahrb. für Min.* 1867, 203.
[3] *Pogg. Ann. Erg. Bd.*, 1873, 6, 363.
[4] *Min. Mitth.* 1873, 29.
[5] *Min. Mitth.* 1873, 215.
[6] *Min. Mitth.* 1873, 216.
[7] *Proc. Cryst. Soc.* 1, 52.
[8] *Ber. Akad.* Berlin, 697 and 915, 1891.
[9] *Zeits. Kryst.* XXIV, 78 and 87.
[10] *Ber. Akad.* Berlin, 243, 1895.
[11] *Zeits. Kryst.* XXVI, 593.
[12] *Zeits. Kryst.* XXVIII, 545.

Digitized by Google

In 1898 Guillemain's[1] *Beiträge zur Kenntniss der natürlichen Sulfosalze* contains analyses of dufrenoysite and jordanite, with some measurements of the latter (Nos. 25, 26, 31, 35).

Mode of Occurrence.

In 1898 I spent part of the summer in the Binnenthal, and there collected a large quantity of material which became the basis for the following investigation.

I handed over to Mr. Spencer the whole of the binnites, comprising about 50 or 60 crystals. Messrs. Prior and Spencer[2] have now published the result of their work on these and other crystals, in a lucid and exhaustive paper, in which they show that binnite is identical with tennantite, so that the name binnite must now be regarded as a local one for tennantite from the Binnenthal.

Though the saccharoidal dolomite is largely developed all along the south side of the Binnenthal, these metallic grey minerals have only been found in the bed of the little Lengenbach, where it cuts through the dolomite deposit, about half a mile from the junction of the little stream with the Binn, nearly opposite Imfeld.

The minerals are obtained by blasting, and the right of doing this is granted by the Commune to a syndicate of seven farmers, who pay a fixed sum yearly for this right. On account of the altitude (5,500 feet) the quarries can only be worked during three months of the summer, and as that is the busiest time for the farmers, it is only on occasional wet days that they can be induced to work for the specimens.

The bed of dolomite, which is nearly vertical, is about 100 to 150 feet thick. In the centre is a layer about 50 feet in width, impregnated with numerous thin veins of small crystals of iron pyrites. These veins carry with them three lodes remarkable for the grey metallic minerals they sparsely contain. Two of them are called the upper lode, and are close together, while the lower lode is about 20 feet lower down the stream. They vary in width from 1 to 3 feet.

Damour's specimens of binnite and dufrenoysite, with all the earlier finds, were obtained from the two upper lodes on the right bank. At the present time the work is carried on upon the left bank, as the old deposit is worked out. Though a good deal of blasting was done on these lodes while I was there, I found no dufrenoysite, but some rathite and

[1] *Inaug. dissert.* Breslau, 1898.

[2] *Min. Mag.* 1898, XII, 184.

Digitized by Google

jordanite, with a comparative abundance of sartorite. In the lower lode a tunnel has been run a short distance under the left bank. It was here that the three fine specimens of dufrenoysite described by Baumhauer were found. I found two small crystals of dufrenoysite, also jordanite, rathite, binnite and sartorite. Sometimes when blasting, a geode about a foot across is exposed, and there the finest crystals are found. The cavity is largely filled with massive yellow dolomite, with a good deal of realgar and blende.

The shock of blasting shatters a number of beautiful crystals; also the mere increase of temperature due to exposure to the sun has often the same effect. I have noticed, especially with rathite, that the warmth of the hand will sometimes cause the crystals to explode with a sharp report, when they break parallel to their best cleavage.

I began working on these minerals in Dresden during the winter of 1898-9, and take this opportunity of recording the fact that I was enabled to do so through the kindness of Prof. Kalkowsky, who gave me the use of the dark room and Fuess goniometer in his well appointed Mineralogical Laboratory. I was not able to continue the work until I returned to Cambridge in the summer of 1899.

The following are the minerals which I have found in the dolomite of the Lengenbach :—

Sartorite	Iron pyrites
Rathite	Barytes
Dufrenoysite	Dolomite
Jordanite	Calcite
Tennantite ("Binnite")	Quartz
Galena	Rutile
Realgar	Hyalophane
Orpiment	Tourmaline
Blende	Muscovite

Chemical Composition.

Mr. Jackson has made analyses of specimens of sartorite, rathite, dufrenoysite and jordanite, the results of which will be found in the tables on pp. 287, 289.

Sartorite.—The crystals of sartorite analysed by Mr. Jackson had been measured, and the density 4·980 was obtained after adding to them the best of my measured crystals.

Analysis No. 1 was from a number of very small brilliant crystals. [illegible]d 8 from larger crystals.

Digitized by Google

Rathite.—Analysis No. 18 was made from crystals very similar to the material analysed by Bömer, and they contained a great many twin lamellæ. The percentage of Pb and S is too high, owing very probably to the inclusion of very minute crystals of galena. Galena is

SUMMARY OF ANALYSES.

		Pb.	S.	As.	Sb.	Ag.	Cu.	Fe.	Total.	S.G.
$PbS+As_2S_3$	Sartorite	42·68	26·39	30·93	..	..	..	..	100	..
	1 Jackson	43·24	25·81	30·80	..	..	..	..	99·85	4·980
	2 ,,	43·93	25·60	30·46	..	..	..	..	99·99	..
	3 ,,	43·72	25·12	30·12	..	..	..	..	98·96	..
	4 Uhrlaub	44·56	25·91	28·56	..	0·42	..	0·45	99·90	5·393
	5 König	46·08	25·26	26·28	..	..	..	..	97·62	5·05
	6 Stockar-Escher	46·83	25·30	26·33	..	1·62	..	..	100·08	5·177
	7 ,,	47·39	25·77	26·82	..	..	.	..	99·98	
	8 Uhrlaub	47·58	24·66	25·74	..	0·94	..	..	98·92	5·405
	9 Stockar-Escher	49·22	24·22	25·27	..	0·94	..	0·25	99·90	5·074
	10 Uhrlaub	49·66	23·95	26·46	..	0·63	..	..	100·70	5·469
$3PbS+2As_2S_3$	Rathite	51·37	23·82	24·81	..	..	..	..	100	..
	11 Jackson	51·51	23·41	24·62	..	..	..	..	99·54	5·412
	12 ,,	51·62	23·62	24·91	..	..	.	..	100·15	5·421
	13 ,,	52·43	24·12	21·96	0·43	..	..	0·33	99·27	..
	14 Bömer	52·98	23·72	17·21	4·53	..	..	0·56	99·0	5·32
	15 Petersen	50·74	23·22	25·83	..	0·21	..		100·0	..
	16 ,,	51·32	25·0	23·93	..	0·12	..	..	100·38	..
	17 Uhrlaub	51·18	24·66	23·32	..	0 02	..	..	99·18	Dark lead grey 5·074
	18 ,,	51·40	24·05	23·95	..	0·02	..	..	99·42	Clear lead grey 5·459
	19 Nason	51·48	23·54	25·14	..	0·17	..	0·08	100·41	..
	20 ,,	51·65	23·82	23·81	..	0·12	..	..	99·40	..
	21 Berendes	52·02	23·11	21·35	.	..	..	..	96·83	..
	22 Stockar-Escher	53·30	23·97	22·01	..	0·24	..	..	99·52	5·355
	23 Berendes	53·62	23·27	21·76	..	0·05	..	0·30	99·00	5·55
$PbS+As_2S_3$	Dufrenoysite	57·18	22·10	20·72	..	..	..	..	100	..
	24 König	57·42	22·55	20·89	..	..	..	..	100·86	5·52
	25 Guillemain	57·38	21·94	21·01	..	..	..	..	100·33	..
	26 ,,	56·73	21·18	20·04	..	..	..	..	97·95	..
	27 Damour	56·61	22·30	20·87	..	0·17	0·22	0·32	100·49	5·549
	28 ,,	55·40	22·49	20·69	..	0·21	0·30	0·44	99·53	
$2PbS+As_2S_3$	Jordanite	68·83	18·64	12·48	..	..	..	..	100	..
	29 Jackson	68·61	18·19	12·32	..	..	..	..	99·12	6·413
	30 ,,	68·83	18·42	12·46	..	..	..	..	99·71	..
	31 Guillemain	68·67	18·81	12·46	..	..	..	..	99·94	5·484
	32 Sipőcz	68·95	18·13	12·86	..	..	..	..	99·94	6·384
	33 ,,	69·99	18·18	12·78	..	..	..	..	100·95	6·401
	34 Ludwig	70·80	17·06	9·90	1·87	..	..	..	99·63	..
	35 Guillemain	72·42	18·50	8·97	..	..	..	..	99·89	..

Digitized by Google

only found in small quantities, often in small curiously rounded crystals, and interpenetrating the other grey metallic substances, especially crystals of jordanite.

I had the opportunity in May 1899 of visiting Freiburg, and through the kindness of Prof. Baumhauer, of comparing his specimens of rathite with those I had found. There is no doubt of the close similarity between the specimen since analysed by Mr. Jackson and Prof. Baumhauer's best specimen.

There is a great difference between the amount of Sb found by Bömer and by Jackson, as will be seen on comparing their analyses Nos. 14 and 13, since the former found 4·53 per cent. and the latter 0·43 per cent. Jackson also made a qualitative analysis of a fragment similar to No. 13, and found only a trace of Sb.

These crystals (No. 13) always contain a visible quantity of iron pyrites, so their density would be misleading. Baumhauer found the specific gravity to be 5·32.

Analysis No. 11 was from two crystals similar in facial development and twinning to Baumhauer's crystal II. The density 5·412 was obtained from five similar measured crystals.

Analysis No. 12 was from large rough crystals with very perfect (010) cleavage given to me by Dr. Grünling. The density 5·421 was obtained from a number of brilliant cleavage fragments. On breaking them open I found some minute crystals.

Dufrenoysite.—I have not yet been able to obtain enough material for Mr. Jackson to analyse, but hope to do so.

Jordanite.—Nos. 28 and 29 from good measured crystals. The density 6·413 was obtained from material including some of my best measured crystals. Total weight of crystals used, 0·775 gram.

Of Guillemain's analyses, No. 31 was made from bright crystals; No. 35 from dull, black material, much fractured, and coated with a white crust of arsenious acid; it is probably altered jordanite.

He gives for the density 5·48024, the mean of five determinations, and cannot explain the great difference between his determination and that of Sipőcz.

This discrepancy is due, I think, to the inclusion of minute crystals of iron pyrites. I first weighed 1·151 gram of jordanite crystals and obtained 5·986 as density, and then by removing crystals which showed the presence of iron pyrites I obtained 6·413, but even this, I think, is a little below the true value for a pure crystal.

Digitized by Google

The following is Mr. Jackson's account of his method of analysis:—

"The mineral, after being crushed, was examined with a pocket lens, and all traces of iron pyrites carefully removed. A qualitative analysis was first made, the elements present being lead, sulphur and arsenic. In the case of one sample small quantities of iron and antimony were found.

"The quantitative estimation was performed by placing a weighed quantity of the mineral in a porcelain boat, placed inside a piece of wide combustion tubing. A current of dry chlorine was passed over it. The decomposition began in the cold, but was completed by gently heating, and finally the mineral was melted. The lead chloride remained behind, as a cream-coloured hard solid, which was allowed to cool, and then weighed.

"The volatile chlorides of sulphur and arsenic were then passed through a couple of flasks containing chlorine water.

"The chloride of sulphur formed readily decomposes in presence of chlorine water into sulphuric acid and hydrochloric acid. The sulphuric acid set free was estimated in the usual way with barium chloride. This method of estimating the sulphur was found to be the best, as there would be a great difficulty in applying the usual method of fusing the mineral with oxidising agents, owing to the insoluble lead sulphate formed.

"The contents of the two flasks having been made up to a given volume, and one portion having been used for estimating the sulphur, the remaining solution was evaporated to a small bulk, to get rid of excess of chlorine, and the estimation of the arsenic was performed by magnesia mixture. The ammonium magnesium arsenate, after precipitation, was dissolved in hydrochloric acid, and precipitated with ammonia and a little magnesia mixture, and finally converted into magnesium pyroarsenate. If antimony was present in the filtrate it was precipitated by sulphuretted hydrogen as pentasulphide, and weighed as such. The results obtained are given in the following table.

	Pb.	S.	As.	Sb.	Fe.	Total.
Sartorite	43·24	25·81	30·80	—	—	99·85
,,	43·93	25·60	30·46	—	—	99·99
,,	43·72	25·12	30·12	—	—	98·96
Rathite	51·51	23·41	24·62	—	—	99·54
,,	51·62	23·64	24·91	—	—	100·15
,,	52·43	24·12	21·96	0·43	0·33	99·27
Jordanite	68·61	18·19	12·32	—	—	99·12
,,	68·83	18·42	12·46	—	—	99·71

"In each case the weight of material used for analysis was between one gram and 0·9 gram." (H. J.)

Digitized by Google

Jordanite $4PbS+As_2S_3$.

Literature.

Vom Rath, 1864, *Pogg. Ann.* CXXII, 387.—Characters.

Sipőcz, 1878, *Min. Mitth.* I, 29.—Analysis.

Wartha, 1878, *Min. Mitth.* 131, 132.—Formula.

Tschermak, ditto, 215.—Crystallography (Nagyág).

Ludwig, ditto, 216.—Analysis.

Vom Rath, 1874, *Pogg. Ann. Erg. Bd.*, VI, 868.—Crystallography.

Lewis. 1877, *Phil. Mag.* (5), V, 139, 1878; *Proc. Crystal. Soc.* I, 52. —Crystallography.

Baumhauer, 1891, *Sitz. Ak. Berlin*, 697.—Crystallography.

Baumhauer, 1891, *Sitz. Ak. Berlin*, 909.—Crystallography.

Baumhauer, 1894, *Zeits. Kryst.* XXIV, 78.—Crystallography

Guillemain, 1898, *Inaug. Diss. Breslau.*—Cryst. and anal.

In the *Zeitschrift für Krystallographie* (Vol. VIII, 1883, pp. 612-622; Vol. IX, 1884, p. 294), and in the *Mineralogical Magazine* (Vol. V, 1884, p. 330), the question of the isomorphism of Jordanite and Meneghinite was discussed by Schmidt, Krenner, Miers and Hintze.

Miers points out that there is a close crystallographic relation between meneghinite and stephanite. The chemical analyses of meneghinite, on which the isomorphism is based, were made upon somewhat unsatisfactory material. The crystals are rare and in the form of needles, of which a great number would be required to obtain a correct analysis.

In my opinion it will probably be found that geocronite is isomorphous with jordanite, having the chemical composition denoted by $4PbS+Sb_2S_3$.

The only crystallographic determination of geocronite was made by Kerndt[1] in 1845 from a rough dull crystal from Pietrasanta, Val di Castello, Tuscany. When I was at Pisa in May, 1899, G. D'Achiardi showed me two large fine crystals from the same locality which A. D'Achiardi had briefly described in 1878.[2] They were found to exhibit the characteristic twin lamellæ of jordanite.

All the analyses that have been made of geocronite were from massive material, and therefore unlikely to be correct.

---

[1] *Pogg. Ann.* LXV, 302.

[2] D'Achiardi, *Min. Tosc.* Vol. II, 352.

Digitized by Google

Crystallography.

System: Oblique.

$a : b : c = 0{\cdot}4945 : 1 : 0{\cdot}2655$. $\beta = 89°26\frac{1}{2}'$ (Baumhauer).

The crystallographic observations were made on 20 crystals obtained from the Lengenbach quarries in August 1898. I have also examined specimens in various museums.

The following table contains a list of 115 known forms, 11 of which have not been observed before.

On account of the change of system, it is not always possible to say which of Baumhauer's planes were observed before by vom Rath, Lewis or Tschermak.[1]

The letters B_1 B_2 B_3 refer to Baumhauer; the subscripts 1, 2 and 3 to his three papers. L to Lewis. R_1 R_2 to vom Rath; the subscripts 1 and 2 to his two papers. S to Solly. T to Tschermak. Those forms marked × I have not observed in the [010, 100] and [010, $\bar{1}$01] zones.

I have always found a great dissimilarity between the + [010, $\bar{1}$01] and − [010, 101] pyramid zones.

Thus in the + zone the planes are clustered about the (010) face, viz. (1.18.$\bar{1}$) (1.17.$\bar{1}$) (1.14.$\bar{1}$) (1.13.$\bar{1}$) (1.12.$\bar{1}$), while in the − zone they are clustered about the (111) face, viz. (121) (131) (141) (151); also as a rule the − zone is always more developed than the + zone.

The prism zone [010, 100] is usually tarnished red, the − pyramid zone bright green, and the + pyramid zone bluish green.

The following four twin laws may be distinguished :—

(I) Twin plane ($\bar{1}$01). This twin plane is always indicated by numerous twin lamellæ.

(II) Twin plane (301) always combined with law (I). This is a new twin law. I have observed it on two crystals.

(III) Twin plane (101). Baumhauer expressed doubt as to the existence of this twin plane. Crystal No. 2, described on page 295, exhibits some striations on the plane (010) parallel to its intersection with (101), which may be very thin twin lamellæ parallel to (101).

(IV) Twin plane (30$\bar{1}$). Baumhauer gives ($\bar{1}$03), but this is a printer's error for (30$\bar{1}$). He determined this law on a small crystal, partly red and partly green, united in nearly parallel position to a beautifully tarnished crystal twinned according to law (I).

---

[1] The following are the positions of the axes adopted by different authors—*a*, *b*, *c* vom Rath, Dana, = *b*, *a*, *c*, Lewis, = *c*, *a*, *b*, Baumhauer.

Digitized by Google

LIST OF KNOWN FORMS.

Symbol.	Indices.	Observer.	Symbol.	Indices.	Observer.	Symbol.	Indices.	Observer.	Symbol.	Indices.	Observer.
a	100	B_1	$\frac{1}{2}r$	250	R_1	$-17q$	1.17.1	$\times B_1$	$+17q$	1.17.$\bar{1}$	S	$+6x$	36$\bar{1}$	B_1
b	010	R_1	$\frac{1}{3}r$	370	B_1	$-14q$	1.14.1	$\times B_2$	$+14q$	1.14.$\bar{1}$	S	$-5x$	351	B_1
c	001	B_1	$\frac{1}{12}r$	12.27.0	$\times B_1$	$-10q$	1.10.1	B_1	$+13q$	1.13.$\bar{1}$	S	$+5x$	35$\bar{1}$	B_1
$-h$	101	B_1	$2r$	120	R_1	$-9q$	191	B_1	$+12q$	1.12.$\bar{1}$	B_2	$-4x$	341	B_1
$+h$	10$\bar{1}$	B_1	$\frac{1}{7}r$	470	B_2	$-8q$	181	B_1	$+11q$	1.11.$\bar{1}$	B_2	$+4x$	34$\bar{1}$	B_1
$-2h$	201	B_1	$\frac{1}{5}r$	230	R_1	$-7q$	171	B_1	$+10q$	1.10.$\bar{1}$	B_1	$-3p$	331	B_1
$+2h$	20$\bar{1}$	B_1	$\frac{1}{4}r$	340	S	$-6q$	161	B_1	$+9q$	19$\bar{1}$	B_1	$+3p$	33$\bar{1}$	B_1
$-3h$	301	B_1	$\frac{1}{5}r$	450	B_1	$-\frac{11}{2}q$	2.11.2	S	$+8q$	18$\bar{1}$	B_1	$-3v$	321	L
$+3h$	30$\bar{1}$	B_1	$\frac{1}{6}r$	670	B_1	$-5q$	151	B_1	$+7q$	17$\bar{1}$	B_1	$+3v$	32$\bar{1}$	B_1
$-5h$	501	B_2	r	110	R_1	$-\frac{9}{2}q$	292	S	$+6q$	16$\bar{1}$	B_1	$-3u$	311	B_1
$+5h$	50$\bar{1}$	B_2	$\frac{1}{2}s$	740	B_2	$-4q$	141	B_1	$+5q$	15$\bar{1}$	B_1	$+3u$	31$\bar{1}$	B_1
..	..	..	$2s$	210	R_1	$-\frac{7}{2}q$	272	B_1	$+\frac{9}{2}q$	29$\bar{2}$	B_2	$-5v$	521	B_2
$8r$	180	B_1	$3s$	310	S	$-3q$	131	B_1	$+4q$	14$\bar{1}$	B_1	$+3z$	23$\bar{1}$	B_1
$\frac{1}{2}r$	2.15.0	$\times B_2$	$4s$	410	B_1	$-\frac{5}{2}q$	252	L	$+\frac{7}{2}q$	27$\bar{2}$	B_1	$+\frac{1}{2}z$	45$\bar{2}$	B_1
$\frac{1}{3}r$	2.11.0	$\times B_2$	$5s$	510	S	$-2q$	121	B_1	$+3q$	13$\bar{1}$	B_1	$-\frac{1}{2}z$	43$\bar{2}$	S
$5r$	150	B_1	..	..	..	$-\frac{3}{2}q$	232	S	$+\frac{5}{2}q$	25$\bar{2}$	S	$-2u$	211	B_1
$\frac{1}{7}r$	290	R_2	$\frac{1}{7}k$	072	B_1	$-p$	111	B_1	$+2q$	12$\bar{1}$	B_1	$+2u$	21$\bar{1}$	B_1
$\frac{1}{12}r$	12.49.0	B_1	$3k$	031	R_2	$-\frac{1}{2}t$	323	T	$+p$	11$\bar{1}$	B_1	$-2y$	412	B_1
$4r$	140	$\times R_1$	$\frac{1}{5}k$	052	L	$-2t$	212	B	$+2t$	21$\bar{2}$	B_1	$+2y$	41$\bar{2}$	B_1
$\frac{1}{3}r$	9.32.0	$\times B_1$	$2k$	021	R_2	$-3t$	313	B_2	$+\frac{3}{2}t$	28.8.2$\bar{8}$	B_1	$-\frac{1}{3}v$	178	B_1
$\frac{1}{7}r$	270	B_1	$\frac{1}{3}k$	032	L	$-4t$	414	T	..	..	..	$+2v$	163	B_1
$\frac{1}{4}r$	7.24.0	$\times B_1$	k	011	R_2	..	..	..	$-8x$	381	B_2	$-\frac{1}{2}v$	158	E_1
$3r$	130	R_1	$\frac{1}{4}k$	047	R_2	..	..	..	$-7x$	371	B_2	$+\frac{1}{2}v$	15$\bar{8}$	B_1
$\frac{1}{4}r$	4.11.0	$\times B_1$	$\frac{1}{4}k$	012	B_1	$+18q$	1.18.$\bar{1}$	B	$-6x$	361	B_1	$+\frac{1}{3}v$	148	B_1

Figure 4 is a stereographic projection representing the law (II) combined with (I). (For Figures 1-3 see Plates 4, 5).

The sign I represents the positions into which the zones are brought by twinning about ($\bar{1}$01).

The sign II represents the positions into which the zones are brought by twinning about (301).

Digitized by Google

TABLE OF CALCULATED ANGLES.

[100 ; 001]		010.	310 = 80°38½′	010,	313 = 85°33½′	[010, 301]	
100,	501 = 20°21½′	,	410 = 82 57	,	414 = 86 40	010,	381 = 41°52½′
,	301 = 31 40½	,	510 = 84 21	,	101 = 90	,	371 = 45 42
,	201 = 42 42	,	100 = 90	..	..	,	361 = 50 5
,	101 = 61 20	..	..	[010, 10$\bar{1}$]		,	351 = 55 7
,	001 = 89 26½	[010, 001]		010,	1.18.$\bar{1}$ = 13 18½	,	341 = 60 51
..	..	010,	072 = 47 6	,	1.17.$\bar{1}$ = 14 3½	,	331 = 67 18
100,	501 = 20 30	,	031 = 51 28	,	1.14.$\bar{1}$ = 16 55	,	321 = 74 25
,	301 = 31 59	,	052 = 56 25½	,	1.13.$\bar{1}$ = 18 10	,	311 = 82 4
,	20$\bar{1}$ = 43 13	,	021 = 62 2	,	1.12.$\bar{1}$ = 19 32	,	301 = 90
,	10$\bar{1}$ = 62 12	,	032 = 68 17	,	1.11.$\bar{1}$ = 21 9½	..	..
,	001 = 90 33½	,	011 = 75 8	,	1.10.$\bar{1}$ = 23 8½	[010, 30$\bar{1}$]	
..	..	,	047 = 81 22½	,	19$\bar{1}$ = 25 19	010,	36$\bar{1}$ = 49 50
[010, 100]		,	012 = 82 26½	,	18$\bar{1}$ = 28 1½	,	35$\bar{1}$ = 54 53
010,	180 = 14 11	,	001 = 90	,	17$\bar{1}$ = 31 18½	,	34$\bar{1}$ = 60 38½
,	2.15.0 = 15 5½	..	..	,	16$\bar{1}$ = 35 21½	,	33$\bar{1}$ = 67 7½
,	2.11.0 = 20 11	..	..	,	15$\bar{1}$ = 40 25	,	32$\bar{1}$ = 74 17½
,	150 = 22 1	..	..	,	29$\bar{2}$ = 43 25	,	31$\bar{1}$ = 81 59½
,	290 = 24 12	[010, 101]		,	14$\bar{1}$ = 46 47	,	30$\bar{1}$ = 90
,	12.49.0 = 26 21	010,	1.17.1 = 14 10	,	27$\bar{2}$ = 50 34½	..	..
,	140 = 26 49	,	1.14.1 = 17 3	,	13$\bar{1}$ = 54 50	[010, 501]	
,	9.32.0 = 29 38	,	1.10.1 = 23 14	,	25$\bar{2}$ = 59 35	010,	521 = 79 32
,	270 = 30 1	,	191 = 25 30	,	12$\bar{1}$ = 64 50½	,	501 = 90
,	7.24.0 = 30 32	,	181 = 28 13	,	11$\bar{1}$ = 76 47	..	..
,	130 = 33 59	,	171 = 31 31	,	21$\bar{2}$ = 83 18	[010, 103]	
,	4.11.0 = 36 10	,	161 = 35 35	,	28.3.$\bar{28}$ = 88 33½	010,	173 = 58 40
,	250 = 38 58	,	2.11.2 = 37 58	,	10$\bar{1}$ = 90	,	153 = 66 30
,	370 = 40 55	,	151 = 40 38½	..	..	..	..
,	12.27.0 = 41 57	,	292 = 43 39	[010, 201]		[010, 10$\bar{3}$]	
,	120 = 45 19	,	141 = 47 1	010,	432 = 74 53	010,	16$\bar{3}$ = 62 21½
,	470 = 49 8	,	272 = 50 48½	,	211 = 79 47½	,	15$\bar{3}$ = 66 25½
,	230 = 53 26	,	131 = 55 3	,	412 = 84 51½	,	14$\bar{3}$ = 70 45½
,	340 = 56 37	,	252 = 59 47	..	..	..	..
,	450 = 58 17	,	121 = 65 1	[010, 20$\bar{1}$]		..	..
,	670 = 60 2	,	232 = 70 44	010,	23$\bar{1}$ = 61 23½	..	..
,	110 = 63 41½	,	111 = 76 53	,	45$\bar{2}$ = 65 33½	..	..
,	740 = 74 13	,	323 = 81 10	,	21$\bar{1}$ = 79 41½	..	..
,	210 = 76 7	,	212 = 83 21½	,	41$\bar{2}$ = 84 48½	..	..

Digitized by Google

The colour is always lead grey, with brilliant lustre, but the faces are very often tarnished red, green, bluish green and yellow.

Streak black. Opaque. Very perfect cleavage parallel to (010), also a parting parallel to ($\bar{1}01$), but interrupted owing to twinning. Fracture conchoidal. Hardness, 3. Specific gravity, 6·384 to 6·418, but according to Guillemain 5·484.

It is sometimes intimately associated with small rounded crystals of galena, and is hardly ever free from included crystals of iron pyrites.

The only other known locality for jordanite besides the bed of the Lengenbach, Binnenthal, is Nagyág in Transylvania.

Description of Specimens.

Out of the 20 crystals measured there are three which are specially worth describing, as they exhibit some new forms, and two show the new twin law on (301).

Crystal 1.

Figure 1, Plate 4.

A flat crystal of rhombic outline, tabular owing to the predominance of (010).

It will be seen from the drawing that the zones [010, 100] and [010, 101] are largely and equally developed, while [010, $\bar{1}01$] is small.

The crystal is twinned about ($\bar{1}01$). A third of the crystal is simple, and on this part, which is represented in the drawing, there are 81 forms developed, besides other minute planes in the zone [100, 001].

The new planes are (292), (340), ($\bar{1}.13.1$) and ($\bar{2}52$).

The zone [010, 101] contains (171), (151), (292), (141), (131), (121), (111), (101).

Zone [010, $\bar{1}01$]: ($\bar{1}.18.1$), ($\bar{1}.13.1$), ($\bar{1}81$), ($\bar{1}71$), ($\bar{1}61$), ($\bar{1}51$), (131), ($\bar{2}52$), ($\bar{1}21$), ($\bar{1}11$), ($\bar{1}01$).

Zone [010,] 010: (180), (150), (140), (130), (250), (120), (470), (230), (340), (450), (100).

	Calc.			Found.
010∧292	= 43°39′	...	...	43°37′
010∧1.13.1	= 18°10′	...	...	18° 8′
010∧$\bar{2}52$	= 59°35′	...	...	59°34′
010∧340	= 56°37′	...	...	56°38′

Digitized by Google

Crystal 2.

Figure 2, Plate 4, and Fig. 4.

I had unfortunately to detach this crystal from its matrix.

In shape it resembles a flat hexagonal prism, with large base and narrow pyramid and prism planes.

It is a unique and beautiful example of a new twin law, twin plane (301), combined with the common twin law, twin plane ($\bar{1}01$).

The new forms present are (510), ($\bar{1}$.17.1) and ($\bar{1}$.14.1). I also found planes which are probably (350), (450) and (515); but the readings are not sufficiently reliable to establish their identity. There is in this crystal, as in Nos. 1 and 3, a great dissimilarity between the + and − pyramid zones.

There are 50 forms present.

Zone [010, 101]: (1.14.1), (191), (161), (151), (292), (141), (131), (272), (121), (232), (111), (313), (101), (515)?

Zone [010, $\bar{1}$01]: ($\bar{1}$.17.1), ($\bar{1}$.14.1), ($\bar{1}$.13.1), ($\bar{1}$.11.1), ($\bar{1}$.10.1), ($\bar{1}$91), ($\bar{1}$81), ($\bar{1}$71), ($\bar{1}$61), ($\bar{1}$51), ($\bar{1}$41), ($\bar{1}$31), ($\bar{1}$21), ($\bar{2}$32), ($\bar{1}$11), ($\bar{1}$01).

Zone [010, 100]: (290), (140), (270), (130), (250), (120), (470), (230), (670), (110), (740), (210), (410), (510), (100), (350), (450)

Zone [010, 001]: (052), (021), (032).

Zone [010, 301]: (311), (301).

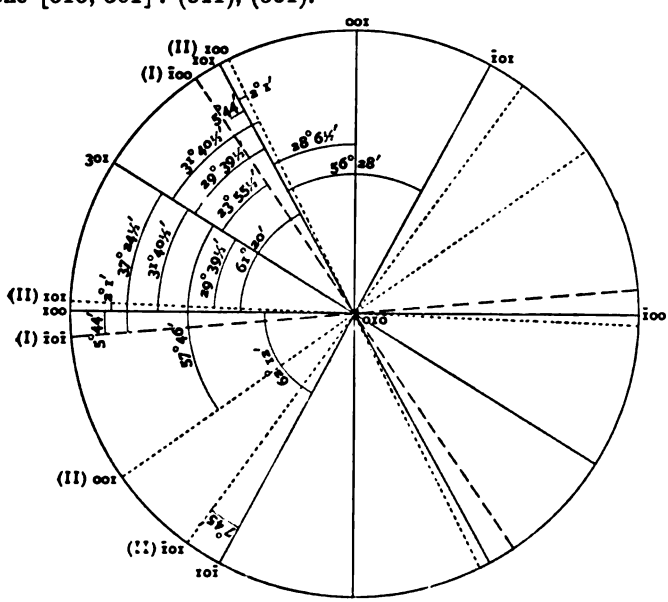


FIG. 4.

Digitized by Google

	Calc.		Found.
010 ∧510 =	84°21′	... ...	84°19′
010∧1.14.1 =	16°55′	... ...	16°50′
010∧1.17.1 =	14°3½′	.. ...	14°

Figure 2 and the stereographic projection, Fig. 4, will explain the manner of growth of this interesting twin.

On each side of the prism zone [010, 100] belonging to the principal crystal is a negative pyramid zone belonging to a crystal twinned upon it; one of these (I) is due to twinning about ($\bar{1}01$), and makes an angle of 5°44′ with the zone [010, 100]; the other (II) is due to twinning about (301), and makes an angle of 2°1′ with the zone [010, 100]; these are shown on the right-hand side of the figure.

The following measurements were obtained:—

	Calc.		Found.
230∧131 (I) =	4°55½′	...	4°45′
230∧131 (II) =	2°8′	...	2°10′
$1\bar{3}1$∧131 (II) =	6°19′	...	6°10′
131∧131 (II) =	47°51′	...	47°55′

On each side of the zone [010, 101] belonging to the principal crystal is a zone of prism faces, one (I) making with it an angle of 5°44′, and the other (II) an angle of 2°1′.

Alongside the zone [010, $\bar{1}01$] belonging to the principal crystal is a zone [010, $\bar{1}01$], making an angle of 7°45′ with it (II).

The faces in the zone [010, 100] are all more developed, especially (250), (120) and (230), than in the other zones.

In the zone [100, 001] the following angles were obtained. The faces (301) and (100) are well developed, and gave sharp images:—

	Calc.		Found.
301∧101	= 29°39½	...	29°41′
301∧101 (II)	= 29°39½	...	29°45′
301∧100 (II)	= 31°40½	...	31°44′
301∧100 (II)	= 31°40½	...	31°38′
301∧101 (I)	= 37°24½	...	37°27′
301∧100 (I)	= 23°55½	...	23°54′

Digitized by Google

Crystal 3.

Figure 3, Plate 5.

A portion of a large very brilliant crystal, which broke on being removed from a cavity in the dolomite, where it was impossible to measure it.

The plane (010) is largely developed with very good cleavage.

The crystal, unlike No. I, is elongated parallel to the axis of the zone [010, 101], and the faces in that zone are largely developed.

The crystal is repeatedly twinned about ($\bar{1}01$), some of the twin lamellæ being broad and well defined.

It is also twinned about (301), but the twinned zones due to this twinning are very small, and only in one zone could reflections be seen; this is not indicated in Fig. 3.

The planes (301) and (412) are unusually largely developed.

There are 55 forms present, in addition to a number of minute planes which gave little or no definite reflection.

The new planes are (310), (2.11.2), (432) and (232).

Zone [010, 101] : (1.10.1), (191), (181), (171), (161), (2.11.2), (151), (292), (141), (272), (121), (232), (111), (313), (101).

Zone [010, $\bar{1}01$] : ($\bar{1}$.18.1), ($\bar{1}$.13.1), ($\bar{1}$.12.1), ($\bar{1}$.11.1), (1.10.1), ($\bar{1}$91), ($\bar{1}$81), ($\bar{1}$71), ($\bar{1}$61), ($\bar{1}$51), ($\bar{1}$31), ($\bar{1}$01).

Zone [010, 100] : (180), (2.11.0), (270), (130), (250), (120), (470), (230), (340), (110), (210), (310), (410), (110).

Zone [010, 301] : (381), (371), (361), (351), (341), (331), (321), (311), (301).

Zone [010, 201] : (432), (211), (412), (201).

	Calc.			Found.
010∧310	= 80°38½′	...	...	80°37′
010∧2.11.2	= 37°58′	...	...	38°
010∧432	= 74°53′	...	...	74°55′
010∧232	= 70°44′	...	...	70°41′

Note.—I hope subsequently to describe the remaining members of this group, but will now briefly state that sartorite crystallises in the oblique, not in the rhombic system, and that rathite requires new crystallographic elements.

Digitized by Google

OBITUARIES.

Carl Friedrich Rammelsberg.

BY the death of Carl Friedrich Rammelsberg on the 28th of December last, the science of mineralogy has lost an enthusiastic votary and the Mineralogical Society a distinguished honorary member. Born in Berlin on the first of April, 1813, Rammelsberg attained the ripe age of nearly 87 years, and could look back on an active scientific career devoted to building up the edifice of mineral chemistry upon the sure foundation which had just been laid down by the great masters when as a young man of 24 he proceeded to the degree of Ph.D. in the University of Berlin. Rammelsberg's first contribution to science was entitled *Ueber das Verhalten des Cyans zum Cadmium*, but the true bent of his mind was quickly revealed by a paper on the composition of berthierite, published in 1837, and by the issue in 1841 of the first edition of the book, now so well known to mineralogists under the title *Handbuch der Mineralchemie*.

In 1841 Rammelsberg established himself as a "Privat Docent" in the University of Berlin, and was called, five years later, to occupy the position of Professor Extraordinarius. At this period his activity was astonishing, and extended not merely to Mineralogy proper, but to the cognate subjects of Metallurgy, Crystallography and the methods of Analytical Chemistry, a many-sidedness traceable to his connection with the Berlin "Gewerbe-akademie," or Technical College.

In 1855 he was elected a member of the Berlin Academy of Sciences, and issued his "Handbuch der Krystallographischen Chemie," a work expanded some twenty-five years later into the treatise familiar to crystallographers.

The second half of Rammelsberg's life was spent in quietly and laboriously pursuing those inquiries to which he had already in his younger days so entirely devoted himself. He became in due course Professor of Inorganic Chemistry in the University of Berlin, and Director of the Second Chemical Laboratory, from which he continued to issue that long series of analyses of minerals of every kind which forms his principal contribution to knowledge and on which his fame must chiefly rest. At the same time he was occupied in collecting material for the

Digitized by Google

two great handbooks which have earned him the gratitude of all his contemporaries. Every few years the appearance of a new edition or a new supplement bore witness not merely to the industry with which he gathered together isolated facts and to the skill with which he marshalled them, but also to the critical judgment that he brought to bear on their interpretation. It was this power of lucid criticism, and the enormous labour freely bestowed in recalculating the results of other workers when a change in the value of an atomic weight seemed to render this desirable, that has conferred on his work a value greater than any possessed by a mere agglomeration of undigested facts. The *Handwörterbuch des chemischen Theils der Mineralogie*, published in 1841, to which five supplements were added in the next twelve years, was entirely re-written, and appeared as the *Handbuch der Mineralchemie* in 1860. Fifteen years later a second completely revised edition was issued, accompanied by a valuable introduction, in which the principles which should guide the analyst in choosing his material and in interpreting his results are set forth with a master's authority.

In 1886 a supplement became necessary, and so lately as 1895 we find the venerable chemist still abreast of the subject, and able to pass through the press a final supplement of 475 pages! In this book industry and power of classification are as conspicuous as ever, mixed now however with some trace of that conservatism which is the almost inevitable accompaniment of old age. It is therefore with no feeling of surprise that we find the man of 81 entering his protest—*Diese Hypothese ist in hohem Grade unchemisch*—against those modern views of the relations prevailing between fluorine and hydroxyl, which seemed to him so subversive of all chemical fitness. Great as is the debt which the mineralogist owes to Rammelsberg, the crystallographer and chemist are under obligation not less deep for the two volumes of the *Handbuch der Krystallographisch-physikalischen Chemie*, published in 1881 and 1882. In this work the author attempted to bring together in convenient form the crystallographical and other physical properties of all substances of which accurate descriptions had been published. Unfortunately, in the hope of making his book more acceptable to the chemist, he adopted the notation invented by Weiss, and rejected the systems of Naumann and Miller, and in so doing succeeded in satisfying no one. To the chemist the book remains almost unknown, and the crystallographer, trained in the more elegant methods of Miller, finds the notation cumbrous and distasteful. Still, although the book failed to do all that its author hoped,

Digitized by Google

the labour expended upon it will always be gratefully recognised by specialists.

As a teacher Rammelsberg enjoyed the distinction of being the founder of the first chemical laboratory in Prussia opened definitely for purposes of instruction. In the performance of the many analyses published by him he doubtless utilised to some extent the assistance of his students; his name, however, appears alone in the titles of the vast majority of the papers, more than 850 in number, attributed to him in the Royal Society Catalogue.

Rammelsberg's papers are mostly to be found in the *Memoirs of the Berlin Academy*, in Poggendorff's *Annalen*, in the *Zeitschrift der deutschen geologischen Gesellschaft*, and in the *Berichte der deutschen chemischen Gesellschaft*, a society of which he was an original founder, and one of the earliest presidents. A. H.

Geheimrath Professor Dr. Geinitz.

Hanns Bruno Geinitz was born on October 16th, 1814, at Altenburg, Saxony. In 1834 he entered the University of Berlin, and in 1836 passed to that of Jena, where he graduated in 1838 with a thesis on the Muschelkalk in Thuringia. In 1850 he became Professor in the Technical High School in Dresden, and in 1857 was also appointed Director of the Royal Mineralogical Museum.

Professor Geinitz's numerous papers deal mainly with palæontological subjects. The colossal task which he set himself at the commencement of his career in Dresden, and to which throughout his life he devoted all his energies, was, as he has himself expressed it, "to investigate the geological history of Saxony in all its epochs, and to perpetuate it in the well-ordered museum."

His principal memoirs are on the Grauwacke and Dyas formations, and on the "Elbthalgebirge," which contains the results of his researches on the palæontology of the cretaceous rocks of Saxony.

As regards mineralogy, the carefully selected specimens of minerals in the Dresden Museum, arranged according to his own system of classification, bear witness to his grasp of the subject, although few of his published works bear directly upon it.

Prof. Geinitz died at Dresden on the 28th of January, in his 86th year. He was elected a foreign member of the Mineralogical Society in 1879.

Digitized by Google

James Reynolds Gregory.

The late J. R. Gregory was born in London, Dec. 29th, 1832, and in early boyhood evinced great interest in minerals and fossils; he was educated at Archbishop Tennison's School in Leicester Square, W.C., and having started in life as an expert in gems, became well known as a geologist and mineralogist. He exhibited in the Paris Exhibition of 1867, where he gained a medal for the excellence of his minerals, &c., and also in the Fisheries and Health Exhibitions. For the Indian and Colonial Exhibition in 1887 he wrote the report of the minerals and gems at the request of H.R.H. the Prince of Wales. He possessed a very wide and extensive knowledge of minerals, gems and meteorites, and was frequently consulted on these subjects by many who appreciated his excellent judgment. His collection of meteorites was formed during a period extending over 40 years, and was an extremely fine one. In 1867 he went to the Cape to prospect for diamonds, and one result of this expedition was the wide introduction into Europe of the now well-known crocidolite from Griqualand.

Mr. Gregory died on Dec. 15th, 1899. He was a member of the Geological Society, of the Mineralogical Society of Great Britain, of the Mineralogical Society of France, of the Geologists' Association, and, until within four years of his death, of the Society of Arts.

Digitized by Google

REVIEWS.

A Treatise on Crystallography. By W. J. Lewis, M.A., Professor of Mineralogy in the University of Cambridge, Fellow of Oriel College, Oxford. Pp. 612: 12 with 538 figures in the text. Cambridge: At the University Press, 1899.

At Cambridge alone of our Universities do any considerable number of students offer mineralogy as one of their subjects for a degree, and no doubt this treatise is primarily intended by Professor Lewis as a text-book for such students. Since few of them possess a very extensive knowledge of mathematics, no analysis, with the exception of the small amount of plane and spherical trigonometry necessary, is introduced in the body of the book, and geometrical proofs alone are adopted. The mathematician is, however, not forgotten, the analytical proofs being given in a chapter towards the end. In this way what is lost in elegance is gained in utility.

The greater part of the book is occupied with an exceptionally elaborate and exhaustive discussion of the thirty-two possible classes of crystalline symmetry, covering seven chapters—one for each of the systems into which the classes may be divided. The fully worked-out examples, of which there are a large number, will prove of invaluable service in rendering the principles of symmetry and the methods of measurement intelligible to the student. Like all recent writers on this subject, the author, following Gadolin, commences with the class devoid of symmetry, and gradually adds elements until the most complicated class is reached; and, following Groth, rejects all ideas of hemihedrism, since each class is in reality independent of any other. The nomenclature adopted involves the production of several new words; uniformity in nomenclature would be desirable, but seems unlikely to be realised. Gadolin's method of showing at a glance the symmetry of the several classes might have been used with advantage; the author's plan is ingenious, but the dots do not readily catch the eye. There is an excellent chapter on twin-crystals. The various types of goniometers and the methods of using them are given in the concluding chapter. Recognising the great importance of graphical methods for the proper understanding of the geometrical relations of crystals, the author quite early in the work introduces two chapters on crystal-drawings and on linear and stereographic projections.

Digitized by Google

The optical and other physical characters were probably considered outside the scope of the treatise, and are only very briefly dealt with. The numerous figures and illustrations add greatly to the value of the book. It is well up to the high standard maintained by the Cambridge Press, and makes a handsome addition to the Cambridge Science Manuals.

First Appendix to the Sixth Edition of Dana's System of Mineralogy. By Edward S. Dana. Pp. 10 and 75. New York: John Wiley and Sons, 1899.

Every one interested in the study of mineralogy will be grateful to Professor Edward Dana for issuing this valuable appendix to the well-known *System of Mineralogy*, for it brings that work abreast of the progress of mineralogical science up to the beginning of last year, and contains in a convenient form a vast amount of important information which could only be arrived at hitherto by wearisome searches through numerous periodicals.

In the course of the seventy-five pages of which the book consists, no less than one hundred and sixty new species or varieties are described or referred to, and many important additions to our knowledge of common minerals are duly chronicled. The minerals are treated in alphabetical order, but a list of new names, arranged according to the chemical classification adopted in the 1898 edition of the *System of Mineralogy*, and the use of heavier type for the more important species, enables the reader to see at a glance the additions made to our knowledge of the various groups. In the case of minerals already known, references to the *System of Mineralogy* are provided. Among the new species of special interest discovered during the past few years Derbylite, Goldschmidtite, Lawsonite, Lewisite, Lorandite, Pearceite and Wellsite attract attention, and bear witness to the activity of mineralogists in America and elsewhere. The reader will, however, probably sympathise with the author when he laments that many new names have been introduced "which have little claim to recognition, either because of the incompleteness of the original examination or the unsatisfactory nature of the material investigated." A useful bibliography gives the titles of upwards of sixty important works bearing on mineralogy, published since 1891. The notation and abbreviations employed are the same as those used in the last edition of the "System." It is to be regretted that this uniformity of treatment was not extended to include the size of page.

Digitized by Google

Repertorium d. min. u. kryst. Literatur. General Register d. Zeitsch. f. Kryst. u. Min. Band XXI-XXX; *Theil* II von Dr. F. Grünling. W. Engelmann, 1890. 860 pp.

This valuable index to the papers on Crystallography and Mineralogy, published during the years 1891-6, will be welcomed by all workers in the two sciences; for though it is only an index to the papers and abstracts which appear in the ten volumes included, it is an almost complete catalogue of all the literature which has appeared during the period, for the *Zeitschrift* is careful to include full abstracts of all papers to which access can be got by the editors, and an author has only himself to blame if his work is overlooked by them.

This repertorium differs in one respect from the two preceding, for papers on the minerals of particular countries or continents are given *twice* under the geographical heading—the first time according to the mineral, the second according to the special locality. This geographical reference is undoubtedly very useful; but I venture to suggest that in future repertoria it should appear as a separate part, and that the division into districts should be a little more systematic. The advantage of the alphabetical index of subjects running on continuously is obvious. As an instance of the latter suggestion I may mention the interpolation of the reference to the Sandwich Islands between Queensland and W. Australia. This is a position where no reader would expect it, and there is no cross reference under the Sandwich Islands to help him. Again, it is somewhat perplexing to have small districts, such as Salzburg, Tirol, Sicily, and Utah, given separately. Few readers know their geography so well as to be quite sure whether a particular valley, *e.g.* the Zillerthal, lies in the Salzburg or Tirol province. Such districts, when forming portions of a particular country, would, it seems to me, best occur as sub-groups of the country.

At the end of the volume is an additional list of errata which occur in Vols. I—XXX. Most of those given for Vols. I—XX are due to Professor Goldschmidt. One regrets, however, that these corrections have been put in small print; their importance to the reader surely entitles them to the honour of larger type, and they are more likely to be correct if so printed. W. J. L.

Digitized by Google

ABSTRACTS.

Theory of Optical Anomalies, Isomorphism and Polymorphism, deduced from the theories of Mallard and Sohncke. (Fréd. Wallerant, *Bull. Soc. Min.* 1898, XXI. 188-256).—Almost at the same time Mallard and Sohncke concluded from the study of the optical properties of crystals, and more especially of rotatory polarisation, that the theory of Bravais is insufficient to explain the properties of certain crystallised bodies, and that we must, in contradiction to the definition of homogeneity adopted by Bravais, admit a diversity of orientations of the molecules. Sohncke enlarged the definition of homogeneity, whilst Mallard studied particular crystals, and determined the structure necessary to explain their properties. Allowing for the slight differences due to the different paths traversed by the two writers, the results obtained are not really dissimilar but complementary. In spite of this concordance the theory of Sohncke has been developed by Schönflies and Fedorow, whilst that of Mallard has been almost completely abandoned. This probably results from the fact that, although Mallard considerably modified his views, he always presented them in the same form.

The author then proceeds to expound the theories of Sohncke in accordance with the ideas held in France. Crystals are composed of similar elements, but often of two kinds, the elements of one kind being superposable and symmetrical to those of the other kind. These elements are without symmetry, and may be called the *fundamental particles*. Homologous points and crystalline structure are defined. A structure of this kind can have the following elements of symmetry:—centres; planes of two kinds, planes of reflexion and planes of gliding; and axes of two kinds, axes of rotation and screw-axes. The author proceeds to enunciate eight theorems dealing with the results of combining different elements of symmetry. Applying these theorems we get groups of symmetry which may be divided into seven systems according to the nature of their lattices. Schönflies's idea of the *fundamental cell* is discussed at some length, and illustrated by the case of a crystalline structure having the elements of symmetry of the hexagonal lattice. A group of such cells which possesses the symmetry of the crystal is called the *complex cell*. To obtain the crystalline structure we must place in each fundamental cell a fundamental particle, the position of which with

Digitized by Google

respect to the cell is constant. The principal advantage of Sohncke's theory and its development by Schönflies and Fedorow is that no restriction is laid on the form of the fundamental particle, and the symmetrical properties of crystals are explained by the structure alone.

Merohedrism.—It is generally supposed that the lattice of a crystal is, of those possessing the elements of symmetry of the crystal, that which has the lowest symmetry; whereas it may be any one of these. Mallard states, in his *Traité de Cristallographie*, "La seule chose qu'il nous soit permis d'affirmer, c'est que le réseau fournit une symetrie au moins égale à celle qui caractérise le système." The optical properties are no longer sufficient to determine the symmetry of a crystal. The fundamental particle has no elements of symmetry, and is naturally biaxial; uniaxial symmetry is produced by twinning about one axis of symmetry, and isotropic symmetry by twinning about more than one axis. The more pronounced the merohedrism the fewer the number of dominant faces, *e.g.* nitrates of lead and barium, which nearly always crystallise in tetrahedra. Mallard has shown that merohedral crystals always tend to form twins about the deficient elements of symmetry. The more pronounced the merohedrism the greater is this tendency; the nitrates mentioned above are nearly always twinned so as to produce octahedra. From the number of possible axes of symmetry and the number of those actually present it is possible to calculate the number of individuals which form a twin. Mallard has shown that in a large number of crystals the lattice is sensibly cubic. Besides this great group there is another in which the lattice is sensibly hexagonal.

Optical anomalies.—Excluding cases of anomalies due to irregular growth, there is no such thing as an optical anomaly. Boracite and a variety of fluor show anomalies, because they are really biaxial though possessing a cubic form. Leucite, again, crystallises in the form {211} at a temperature where it is really isotropic. On cocling, each crystal is transformed into a large number of orthorhombic crystals, the faces of which make very small angles with the original faces. A casual examination would, therefore, lead us to suppose that the original faces still exist, but they have in reality disappeared. Merohedral crystals are nearly always twinned, and on the degree of interpenetration of the individuals will depend the amount of variation in the optical characters.

Isomorphous mixtures.—A study of isomorphous mixtures shows that they are analogous to other molecular mixtures. The changes in the lattice elements are represented by a curve which, just as in the case of the

Digitized by Google

elasticity of a mixture of two gases or the fusing point of an alloy, is in general an arc of an hyperbola. In particular cases this may approximate to a straight line, but there is no reason *à priori* for assuming a law of proportionality. In many cases the symmetry of the mixture differs from that of the two bodies composing the mixture. In fact the complex particles do not retain their individuality, but a new complex particle is formed which may have the same or a different symmetry.

Polymorphism.—This is usually taken to mean the property possessed by certain substances of crystallising in forms incompatible with one another, but it should include changes of structure which are revealed by changes in symmetry, but not in form, and also by changes in other physical characters, but in neither form nor symmetry. Crystals of the same substance occur at times with merohedral, and at times with holohedral symmetry. The latter case is usually explained as a combination of two enantiomorphous forms, but there is no reason *à priori* for supposing this to be so. The study of the optical characters gives incomplete information. The study of the figures produced by corrosion gives far more complete, but in cases contradictory, information. This is due to polymorphism, which should be recognised in substances produced in nature just as in those produced in the laboratory, *e.g.* sulphur. Nitrate of lead is usually enantiomorphous, but if very slowly precipitated it is holohedral. Cuprite is hemihedral according to Miers, but the crystals from Chessy are holohedral. When the change is only in the symmetry the density and lattice remain unaltered. In quartz, orthoclase, zoisite, &c. we have two structures differing only in the orientation of the particles, which may be combined in the same crystal. We may also have the more complicated case in which the two structures have the same lattice and density, but not the same elements of symmetry. The author shows why a deformation of the lattice occurs on changing to a structure of lower symmetry. The paper finally closes with a complete discussion of the various structures that are found in boracite, andradite and boleite.

G. F. H. S.

New Minerals from Chili, a New Occurrence of Utahite and a New Carbonate of Bismuth from Schneeberg. (A. Arzruni[1] and K. Thaddéeff, completed and edited by A. Dannenberg, *Zeits. Kryst. Min.* 1899, XXXI,

[1] Arzruni died on September 22nd, 1898, before the publication of this paper, the production of which was undertaken by Herr Dannenberg. The chemical work is by Thaddéeff, who has since died (on October 16th, 1899).

Digitized by Google

229-247).—1. *Arzrunite* is found as a drusy crystalline lining in the small cavities in a quartz vein, and seldom forms good crystals. The colour of this crust is bright blue inclining to green. The largest crystal found is barely 1 mm. in length and about half this in breadth. The habit is apparently hexagonal, but the optical examination showed that the mineral is really rhombic. It displays strong pleochroism when viewed through different pairs of faces belonging to the apparently hexagonal prism, the colour varying from deep to very weak blue. The faces, which are almost colourless in parallel light, show in convergent light an optic axis which emerges nearly at right angles. The axial ratios are $a:b:c=0{\cdot}5773:1:0{\cdot}4163$, and the forms observed (110), (010), (111), (021), (001). Associated with this mineral was a little daviesite with forms (100), (110), (121).

2. *Stelznerite* is found at Remolinos, Vallinar, Chili, forming green transparent prismatic crystals, which show strong pleochroism, blue-green parallel to the prism edge and yellow-green in the perpendicular direction. The plane of the optic axes is parallel to (001), and the axes emerge nearly at right angles to the prism faces. The axial ratios are: $a:b:c=0{\cdot}50368:1:0{\cdot}70585$, and the forms observed: (111), (110), (010), (011), (001).

3. *Rafaelite* is found at the Mina San Rafael, Sierra Gorda, in the form of transparent needles (about 0·5-1 mm. long and 0·2-0·5 mm. broad) on galena, quartz and celestite. Pleochroism strong: deep violet parallel to length, and violet-red perpendicular. An interference figure is visible through (100): one axis with broader rings and the other with narrower. Extinction: parallel to length. Lustre: metallic adamantine. System: monoclinic, $a:b:c=0{\cdot}9084:1:1{\cdot}2086$; $\beta=62°47'$. Forms present: (100), (001), ($\bar{1}01$), ($\bar{1}02$), ($\bar{2}01$), ($\bar{3}01$), ($\bar{1}08$), (101), (201), (110), (130), (010), (132), (432). Crystals are usually twinned about (100).

4. *Utahite* was originally described by Arzruni in 1884 (*Zeits. Kryst. Min.* 1884, IX, 558), and since then only a doubtful occurrence has been noticed by Genth (*Zeits. Kryst. Min.* 1890, XVIII, 590). It has now been found at the Mina Santa Rosa, Guanaco, Taltal, Chili, associated with native gold on yellow-brown quartz. The habit is pseudo-regular, but really composed of the rhombohedral forms (100), (11$\bar{1}$) and (111), of which the second is new. The measurements are not in very close greement with those previously obtained.

Digitized by Google

Chemical investigations by K. Thaddéeff.

1. *Arzrunite.* Two analyses were made which, after deducting as impurities the SiO_2, Fe_2O_3, CaO and ZnO, correspond closely to the formula: $PbSO_4.PbO + 3(CuCl_2.H_2O) + Cu(OH)_2$.

2. *Stelznerite.* Sp. gr. determined in water, in which the mineral is insoluble, is 3·884 (mean of five). The analysis agrees with the formula: $CuSO_4.2Cu(OH)_2$.

3. *Rafaelite.*[1] Sufficient material was not available for quantitative analysis; a qualitative analysis showed it to be an oxy-chloride of lead.

4. *Utahite.* An analysis of 0·0229 g. agrees with Damour's, with the exception of a larger amount of water, and gives the formula: $Fe_2O_3.SO_3.2H_2O$.

5. *Brochantite* from the Mina Montecristo, Paposo, Chili, gave the usual formula: $CuSO_4.3Cu(OH)_2$.

6. *Basic Carbonate of Bismuth.* The yellow powder was separated from quartz in methylene iodide, but the analysis still showed the presence of 8 % quartz. The analysis gave the formula: $5Bi_2O_3.H_2O.CO_2$,

G. F. H. S.

Optical Studies 1. (C. Klein, *Sitzungsb. k. preuss. Ak. Berlin*, 1899, XIX, 346-364).—1. *The optical constants of Anorthite from Vesuvius.* After discussing previous work the author gives the result of his own investigations, and finally concludes that the second positive mean-line is for medium colours normal to (021). The plane of the optic axes is inclined at an angle of about 60½° to the projection of the *a*-axis on this face. The true axial angle is 76°30′ for Na light. The birefringence is negative about the first mean-line; $\rho < v$ with inclined dispersion.

2. *The use of the method of total reflexion in petrography.* Any face is sufficient to determine the three principal indices of refraction of a biaxial crystal. The author describes the method of using the total reflectometer, and gives the constants of those rock-forming minerals which have at least one refractive index sufficiently low. G. F. H. S.

Formula of Tourmaline.—S. L. Penfield and W. H. Foote, in a recent paper (Abstract, *Min. Mag.* XII, 216), have considered all varieties of tourmaline to be salts of the alumino-borosilicic acid

$$H_9Al_3(B.OH)_2Si_4O_{19} = H_{20}B_2Si_4O_{21},$$

[1] Identified with paralaurionite, this vol. p. 183, and *Zeits. Kryst. Min.* 1900, XXXII, 217.

Digitized by Google

the H_2 being wholly or partly replaced by aluminium, magnesium, iron and alkalies. This formula has been criticised in three later papers, and other formulæ have been given.

H. Rheineck (*Zeits. Kryst. Min.* 1899, XXXI, 385-386), by combining the fluorine with the metals instead of uniting it with hydroxyl, arrives at acids represented by the two general formulæ

$$H_5Al_5B_3Si_6O_{31} \text{ and } H_{14}Al_5B_3Si_6O_{31}$$

with the intermediate members

$$H_8Al_7B_3Si_6O_{30} \text{ and } H_{11}Al_6B_3Si_6O_{31}.$$

F. W. Clarke (*Amer. Journ. Sci.* 1899 [iv], VIII, 111-121) argues in favour of the formula proposed by him in 1895 (*Bull. U.S. Geol. Survey*, No. 125), namely $2[Al(SiO_4)_3R'''_2(Al.BO_3)]:Al(BO_3)R'_2$, which is a derivative of the normal aluminium orthosilicate $Al_4(SiO_4)_3$ employed by the author in explaining the composition of most natural silicates (Abstr. *Min. Mag.* X, 335; XI, 37). This formula expresses the relation which exists between the micas and tourmalines, as shown by their mode of origin, occurrence, alteration, &c. Clarke's formula reduces to one of the acids assumed by Rheineck, namely $H_{14}Al_5B_3Si_6O_{31}$.

G. Tschermak (*Tsch. Min. Mitth.* 1899, XIX, 155-164) also proposes formulæ to bring out the relations between the micas and tourmalines, in the same way that he has previously done for the plagioclase and scapolite groups. Here the composition of any tourmaline is explained by the isomorphous mixing of the three molecules:—

$$Si_{13}B_6Al_{16}Na_4H_8O_{68} = B_6Al_4O_{15}.4(Si_6Al_6NaH_2O_{12}) = Tu$$
$$Si_{12}B_6Al_{10}Mg_{12}H_6O_{63} = B_6Al_4O_{15}.2(Si_3Al_3H_2O_{12}.Si_3Mg_6O_{12}) = Tm$$
$$Si_{12}B_6Al_8Mg_{12}H_8O_{61} = B_6Al_4O_{15}.2(Si_3Al_2H_4O_{11}.Si_3Mg_6O_{12}) = Tn$$

Each of these is written partly as a borate and partly as a silicate, the silicate portion of each being the formula of paragonite, meroxene and phlogopite respectively. Penfield and Foote's recent analyses are satisfied by the formulæ $Tu_{44}Tm_7$ (Haddam Neck) and $Tu_{13}Tm_{27}$ (De Kalb).

L. J. S.

The Parent-rock of the Diamond in South Africa. (T. G. Bonney, *Proc. Roy. Soc.* 1899, *LXV*, 223-236; *Nature*, 1899, *LX*, 620).—In the "blue ground" of the Newlands mines, in West Griqualand, and about 40 miles N.W. of Kimberley, are rounded boulders of eclogite (a holocrystalline rock composed of garnet and diopside) which rarely contains colourless octahedra of diamond apparently as an original constituent. Previously the only mineral found in intimate association with the diamond

Digitized by Google

was garnet. The water-worn character of the eclogite boulders proves that the "blue ground" is not of igneous origin, but a breccia produced by the destruction of various rocks, including the eclogite which has contributed the diamonds to the mixture. L. J. S.

Cosmic Origin of Moldavite. (F. E. Suess, *Verh. kk. geol. Reichs. Wien*, 1898, 387-403).—Moldavite, or bottle-stone, which resembles green bottle-glass in appearance, has long been found in deposits of late tertiary or early quaternary age in the Moldau district (Bohemia) and at a few other localities in Bohemia and Moravia. It has been considered by some to be an artificial glass, and by others to be obsidian. The fragments have peculiar surface markings which the present author maintains cannot have been produced by attrition in water, and he points out their similarity to the pittings of meteorites produced by enormous air resistance. It is therefore concluded that moldavites are of cosmic origin, and that they represent a hitherto unrecognised type of aerolites. The "obsidian-bombs" of Australia and the Dutch East Indies are probably of the same origin.

C. v. John (*Ibid.* 1899, 179-182) gives the results of analyses made of moldavite; they show the presence of about 80 per cent. of silica and 10 per cent. of alumina, with small amounts of iron, calcium, magnesium and potassium. The chemical composition of material from different localities varies only slightly, and is very different from that of artificial glass. L. J. S.

Constitution of Pectolite, Pyrophyllite, Hemimorphite and Analcite. (F. W. Clarke and G. Steiger, *Amer. Journ. Sci.* 1899 [iv], VIII, 245-257).—In continuing the investigation of the constitution of natural silicates special importance is attached to the two following reactions (Abstr. *Min. Mag.* X, 81): (1) when talc is ignited there is a liberation of one-fourth of the silica, which can be extracted by boiling with sodium carbonate solution; this suggests that other acid metasilicates may behave in a similar way. (2) Dry ammonium chloride, at its temperature of dissociation, acts differently on different minerals.

Pectolite, after ignition, gives up 8·68 per cent. of silica, which is one-sixth of the total amount; this supports the usual acid metasilicate formula for the mineral, namely $HNaCa_2Si_3O_9$.

Pyrophyllite has the empirical formula $AlHSi_2O_6$, which is apparently that of an acid metasilicate, but on ignition there is only about 2 per cent.

Digitized by Google

of silica liberated; the formula is therefore written as $(AlOH)Si_2O_5$, that is, as a basic salt of the acid $H_2Si_2O_5$. The mineral is very slightly attacked when heated with dry ammonium chloride.

Hemimorphite is represented as a basic metasilicate by the usual formula $(ZnOH)_2SiO_3$: here both the hydrogen and the zinc are combined in one way, and in all other possible formulæ they must be represented as present in at least two modes of combination. Several experiments were made with the idea of extracting a definite fraction of the zinc and water, but the results were negative and only tend to support the usual formula; no silica is, however, liberated on ignition.

Analcite, when heated at 350° with dry ammonium chloride, has about half the sodium converted into chloride, and the residue has the composition $H_2Na_2Al_4Si_8O_{24}.NH_3$. This ammonia derivative, which is not decomposed by a hot solution of caustic soda, suggests that the analcite formula should be quadrupled, giving $Na_4Al_4Si_8O_{24}+4H_2O$. The excess of silica shown by some analyses of analcite over that required by this formula is explained by analcite being, not a metasilicate, but a mixture of ortho- and tri-silicate; the general formula being $NaAlX+H_2O$, where

$$X=nSiO_4+mSi_3O_8.$$

This explains the alteration of albite ($NaAlSi_3O_8$) and nephelite ($NaAlSiO_4$) to analcite. For normal analcite the formula is finally written as $Al_4Na_4(SiO_4)_3(Si_3O_8)_2+4H_2O$. This is written structurally to show the relation between analcite, leucite and the garnet-sodalite group. L. J. S.

Nature of Water of Crystallisation. (F. Rinne, *Neues Jahrb. f. Min.*, 1899, I, 1-31).—The water of crystallisation of a salt behaves in many ways like ordinary free water; for example, it gradually evaporates, especially at a slightly elevated temperature, and in some salts there are certain points analogous to the boiling point of ordinary water. Copper sulphate ($CuSO_4+5H_2O$) when quickly heated gradually rises in temperature to 105°, and remains at this temperature until $2H_2O$ has been expelled; the temperature then again rises to 117°, when the boiling point of the second $2H_2O$ is reached; the boiling point of the last molecule of water is 258°; a less sharply marked point is 99°, where $\frac{1}{2}H_2O$ is lost. For barium chloride ($BaCl_2+2H_2O$) the boiling points in each molecule of water are 105° and 162°. These boiling points vary with the atmospheric pressure.

Heulandite and stilbite are examples of another group of substances in which the water of crystallisation behaves in quite a different manner.

Digitized by Google

Here there is nothing analogous to boiling point, the water being lost gradually and *pari passu* with the rise in temperature. At the same time there is a gradual change in the optical orientation of the crystals (Abstract *Min. Mag.* XI, 343): in the case of heulandite the optic axes pass three times through a uniaxial position. The amount of water lost at any particular temperature is less, the greater the atmospheric pressure and the greater the amount of moisture in the air.

In these two groups the relation of the water of crystallisation to the salt can be considered to be in the first case that of a molecular compound, and in the second case that of a solid solution. L. J. S.

Minerals of Japan. (K. Jimbō, *Journ. Sci. Coll. Imp. Univ. Tōkyō*, 1899, XI, 213-281).—A description is given of 128 mineral species found in Japan, with notes on their occurrence at the various localities. In the pegmatite veins in the granite near Takayama in province Mimo, and near Tanokamiyama, prov. Ōmi, are found good crystals of topaz, felspar and quartz, together with beryl, tourmaline, &c., and the tin placers of the Takayama district contain cassiterite, sapphire, topaz, wolframite, fergusonite, &c. The well-known quartz-twins, in which the axes of the two individuals are nearly at right angles (twin plane $\xi(\bar{1}25)$), come from Narushima, one of the Gotō Islands, from the neighbourhood of Kōfu, and other localities; from Kōfu are twin crystals nearly 25 cm. across. The clear quartz crystals from which the large crystal balls (up to 13 cm. diameter) are cut, come from the province Kai. Good specimens are found of hyalite, arsenic, stibnite, anorthite, ilvaite, axinite, danburite, &c.; and the occurrence of the rare mineral matildite is recorded. L. J. S.

Experiments on the Formation of Minerals in Magmas. (J. Morozewicz, *Tsch. Min. Mitth.* 1898, XVIII, 1-90, 105-240).—In this important paper are described the results of numerous experiments made with the idea of discovering the conditions under which various minerals crystallise from magmas. The experiments were made on large amounts of material (up to 1 cwt. or more) heated in fire-clay crucibles in a Siemens' furnace at glass-works at Warsaw. The material, after fusion at 1600° C., was allowed to remain in successively cooler parts of the furnace for several weeks or months. Numerous (54) chemical analyses were made of the resulting rocks, and of the crystallised minerals isolated from them. A list of the minerals produced includes all the more important rock-forming minerals with the exception of hornblende, and the crystallised fusions represent almost all the known types of alumino-silicate rocks.

Digitized by Google

The conditions for the formation of corundum, spinel, sillimanite and cordierite in silicate magmas are summarised as follows. In supersaturated alumino-silicate magmas of the general composition

$$(Ca,Na_2,K_2)O.mAl_2O_3.nSiO_2 (n = \text{or} > 2),$$

the whole of the excess of alumina $(m-1)$ separates out: (*a*) as corundum if no magnesia or ferrous oxide is present, and if $n < 6$; (*b*) as sillimanite, or as sillimanite and corundum, if $n > 6$. When the magmas are rich in magnesia and ferrous oxide, the excess of alumina separates out: (*c*) as spinel, or spinel and corundum, if $n < 6$; and (*d*) as cordierite, or cordierite and one or more of the other minerals, if $n > 6$.

Magmas having the composition of anorthite ($CaO.Al_2O_3.2SiO_2$) and albite ($Na_2O.Al_2O_3.6SiO_2$) are therefore capable of dissolving excess of alumina, which crystallises out, on cooling, as corundum: and excess of silica and alumina in an albite magma separate out as sillimanite and corundum. An anorthite magma dissolves about 5 per cent. of alumina (in the form of bauxite), and a nephelite magma about 29·5 per cent. The corundum crystals obtained are tabular in habit, and reach a diameter of 1·5 mm.: the various colours—blue, red, yellow—may be explained by the presence of oxides of iron. The spinel octahedra are colourless, yellow, green, or black, depending on the amount of iron present. Natural magmas containing an excess of alumina, from which corundum, spinel, sillimanite and cordierite have crystallised, are of comparatively rare occurrence; several cases are known where there has been an absorption by the magma of clay-slate at the contacts, and veins of corundum-felspar-rocks in the granites, etc. of the Ilmen Mountains, Urals, are described. Kyschtymite is the name given to a corundum-anorthite rock, from the Kyschtym district, which contains 50—60 per cent. of corundum and some spinel.

The pyroxene and the sodalite-nosean groups are treated in a similar manner. To the latter group belongs a product to which the name lagoriolite or soda-garnet is given; this has the garnet formula

$$3(Na_2,Ca)O.Al_2O_3.3SiO_2,$$

and forms a connecting link between the garnet and the nosean groups. The largest amount of alkali yet found in natural garnet is 4·22 per cent. in melanite from the phonolite of Oberschaffhausen.

Acid magmas do not readily crystallise, and, as a rule, they solidify to glass. When, however, the experimental magmas have crystallised, the excess of silica has separated as tridymite or in a prismatic modification the characters of which are as yet unknown. A liparite magma fused

Digitized by Google

with one per cent. of tungstic acid gave crystals of quartz, biotite and sanidine, proving that the essential constituents of granite can be formed by dry fusion.

The order in which various minerals separate from the magmas is discussed: it does not depend, as has been stated, on the fusibility or basicity of the minerals, but on their solubility and the relative amounts in which they are present in the solution. L. J. S.

New Minerals from Franklin Furnace, New Jersey.—Few localities have yielded a greater variety of minerals than the zinc mines at Franklin Furnace, Sussex Co., New Jersey, where over fifty species have been found. The ores occur in a white, crystalline, dolomitic limestone near its contact with granite, and many of the minerals are of metamorphic (pneumatolitic) origin. The minerals recently described from the locality include native copper (J. E. Wolff, *Proc. Amer. Acad. Arts and Sci.* 1898, XXXIII, 429) and native lead (W. M. Foote, *Amer. Journ. Sci.* 1898 [iv], VI, 187) and the new minerals, caswellite (Abstract, *Min. Mag.* XI, 243), rœblingite (Abstr. *Min. Mag.* XI, 343), and clinohedrite (Abstr. *Min. Mag.* XII, 138). Still more recently the following new minerals have been described. It is remarkable for so many new minerals to be described from a locality where extensive mining operations have long been carried on.

Hardystonite. (J. E. Wolff, *Proc. Amer. Acad. Arts and Sci.* 1899, XXXIV, 479; and *Zeits. Kryst. Min.* 1899, XXXII, 1).—This occurs as white granular masses, with a vitreous lustre, and is mixed with grains of willemite, rhodonite and franklinite. Sp. gr. = 3·396; H = 3-4. The microscopical examination of thin sections shows the mineral to be tetragonal, with good basal and prismatic cleavages; it is optically uniaxial and negative. The following analysis, made on material containing a few specks of franklinite and willemite, gives the formula $ZnO.2CaO.2SiO_2$:—

SiO_2.	ZnO.	MnO.	CaO.	MgO.	Fe_2O_3.	Loss on ignition.	Total.
38·10	24·30	1·50	33·85	1·62	0·57	0·52	100·46

S. L. Penfield and C. H. Warren (*Amer. Journ. Sci.* 1899 [iv], VIII, 339-353; and *Zeits. Kryst. Min.* 1900, XXXII, 227-242) have described the following, the account of which (except leucophœnicite) was first published in the First Appendix (1899) to Dana's *System of Mineralogy*. The associated minerals are native copper and lead, clinohedrite, rœblingite, axinite, willemite, datolite, garnet, phlogopite, &c.

Digitized by Google

Hancockite occurs as brownish-red cellular masses of minute, lath-shaped crystals, which are monoclinic, and have nearly the same habit and angles as epidote. Single crystals are yellowish-brown with a vitreous lustre, and are pleochroic. Sp. gr. = 4·030. Analysis by Warren gives the epidote formula—

$$H_2R''_4R'''_6Si_6O_{26} \text{ or } R''_2(R''.OH)R'''_2(SiO_4)_3;$$

but the mineral differs from epidote in containing lead and strontium isomorphous with calcium.

SiO_2.	Al_2O_3.	Fe_2O_3.	Mn_2O_3.	PbO.	MnO.	MgO.	CaO.	SrO.	H_2O.	Total.
30·99	17·89	12·33	1·38	18·53	2·12	0·52	11·50	3·89	1·62	100·77

Glaucochroite occurs, embedded in nasonite, as columnar orthorhombic crystals of a delicate bluish-green colour, resembling beryl. Twins are sometimes present, with individuals intercrossing at angles of about 60°. H. = 6; sp. gr. = 3·407. The approximate parameters, $a:b:c = 0·440:1:0·566$, and the optical characters indicate that the mineral belongs to the olivine group. The analysis (No. I below) gives the formula $CaMnSiO_4$, showing that the mineral takes a place next to monticellite ($CaMgSiO_4$).

Nasonite is white and massive, with a greasy to adamantine lustre. Thin sections under the microscope show the mineral to be crystalline and optically uniaxial; the system is probably tetragonal. Sp. gr. 5·425. After deducting a little clinohedrite the analysis (II) gives the formula $Pb_6Ca_4Cl_2(Si_2O_7)_3 = Pb_4(PbCl)_2'Ca_4(Si_2O_7)_3$. This is closely related to the tetragonal ganomalite from Sweden, for which the formula is usually given as $Pb_3Ca_2Si_3O_{11} = Pb_4(Pb_2O)''Ca_4(Si_2O_7)_3$; in place of this the new formula $Pb_4(Pb.OH)_2'Ca_4(Si_2O_7)_3$ is proposed. Nasonite, therefore, differs from ganomalite in containing chlorine in place of hydroxyl. These, together with cordierite, barysilite ($Pb_3Si_2O_7$) and hardystonite, are salts of the acid $H_6Si_2O_7 (= H_2SiO_3 + H_4SiO_4 = 2Si(OH)_4 - H_2O)$, for which the name mesosilicic acid is proposed in place of the usual term diorthosilicic acid.

Leucophœnicite is purplish-red to raspberry-red in colour; it has a crystalline structure, though the crystal system, possibly monoclinic, could not be determined. Sp. gr. = 3·848. Analysis III (also Na_2O,0·39; K_2O,0·24) gives the formula $H_2R_7Si_3O_{14}$, or, as the water is not expelled below a red-heat, $R_5(R.OH)'_2(SiO_4)_3$. This represents a basic orthosilicate, and the mineral is therefore a manganese humite with hydroxyl in place of fluorine.

	SiO_2.	PbO.	MnO.	ZnO.	MgO.	CaO.	FeO.	Cl.	H_2O.	Total.
I.	31·48	1·74	38·00	—	—	28·95	trace	—	—	100·17
II.	18·47	65·68	0·83	0·83	—	11·20	0·10	2·81	0·26	99·54
III.	26·26	—	60·63	3·87	0·21	5·67	trace	—	2·64	100·01

L. J. S.

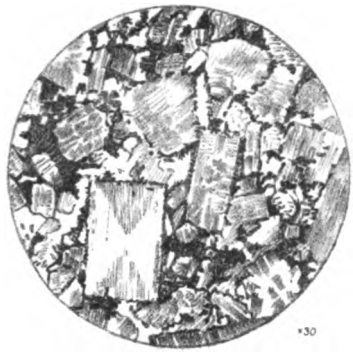
Digitized by Google

Digitized by Google

Digitized by Google

1

2



3

4

5

6

F. Drake del. et lith.

West, Newman imp.

Digitized by Google

Digitized by Google

Digitized by Google

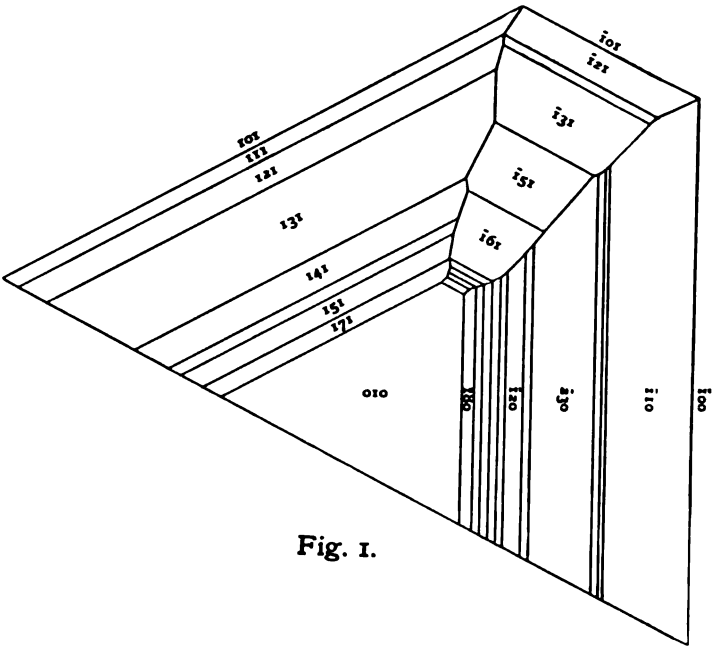


Fig. 1.

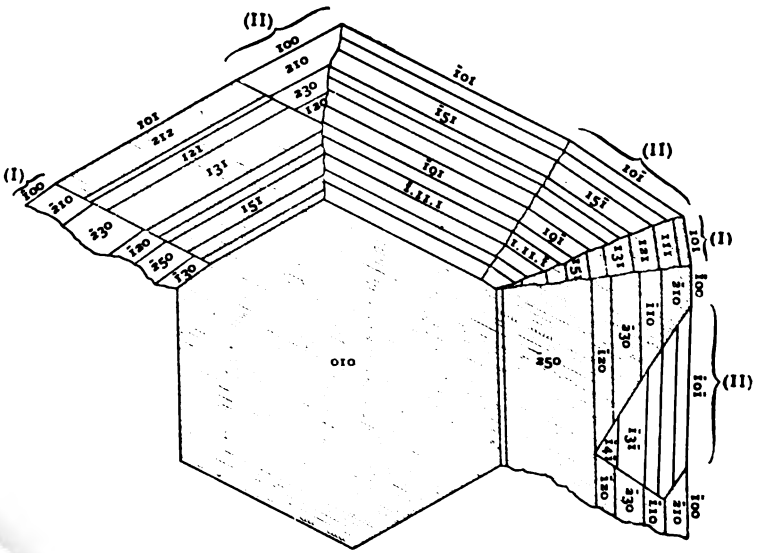
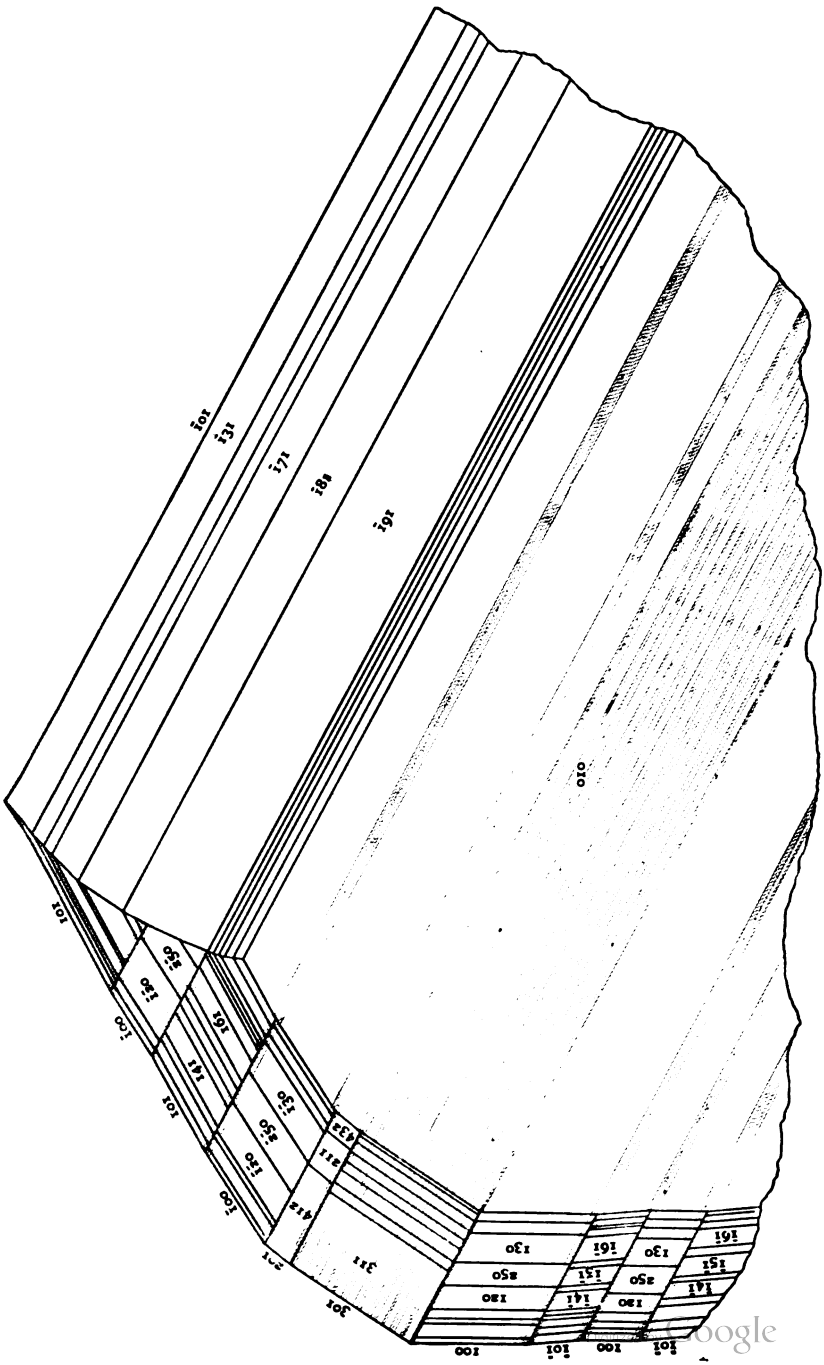


Fig. 2.

Digitized by Google


101
131
171
181
191
010
100
101
100
101
100
101

Digitized by Google

THE MINERALOGICAL MAGAZINE

AND

JOURNAL

OF THE

MINERALOGICAL SOCIETY.

No. 58. NOVEMBER, 1900. Vol. XII.

Petrographical Notes on the Rock-Specimens collected in the Little Island of Trinidad, S. Atlantic, by the Antarctic Expedition of 1839-43, under Sir James Clark Ross.

By G. T. Prior, M.A., F.G.S.,

Assistant in the Mineral Department of the British Museum.

[Read January 23rd, 1900.]

THE Little Island of Trinidad, as it is called to distinguish it from the larger island in the West Indies, is situated in the South Atlantic Ocean, about 700 miles off the coast of Brazil, in lat. 20°31′ S. and long. 29°19′ W.

According to Ross,[1] who in 1839 effected a landing on the N.W. coast, the island is a mass of volcanic matter, the rocks of which it is composed assuming the most extraordinary shapes. The most remarkable of these are the Sugar Loaf Hill on the southern and the Nine-Pin Rock on the north-western coast. The latter is described as consisting of "greenstone" (phonolite, see below), and rising to a height of 850 ft. almost perpendicularly from the sea in the form of a beautifully proportioned column. It is attached on the land side to a ridge of hills, two or three hundred feet high, also composed of "greenstone," like the perpendicular

[1] *A Voyage of Discovery and Research in the Southern and Antarctic Regions during the years 1839–43.* London, John Murray, 1849.

Digitized by Google

cliffs which opposed an insuperable barrier between the beach on which the landing was effected and the interior of the island.

Further details concerning the extraordinary physical features of this desolate volcanic island are given by E. F. Knight,[1] who conducted an expedition there in search of a treasure supposed to have been hidden by pirates. According to Knight, Trinidad is a precipitous mass of barren volcanic rock studded with sharp, needle-like peaks, the highest of which is about 3,000 ft. above sea-level. It is about 15 miles in circumference, and is surrounded by sharp coral reefs. The conical hill on the S.E. known as the Sugar Loaf is about 1,500 ft. high. It is described by Knight as "apparently of grey granite," but, like the Nine-Pin Rock it most probably consists of phonolite.[2]

The rock close to it, called from its peculiar shape "Noah's Ark," is 800 ft. high, and is referred to as "probably a crater." Certainly, in East Bay, in the neighbourhood of these rocks, the signs of volcanic activity were more evident than elsewhere, in a succession of streams of black basaltic lava, ledges of which extend far out to sea. A peculiarity of the island insisted on by Knight is that it is nowhere solid, but rotten throughout. The lower slopes on the western side are composed of *débris*, with loose stones of every size easily dislodged, and even the columns of basalt forming precipitous walls rising hundreds of feet high above this *débris* are described as rotten and crumbling away under the tread, so that the ascent to the grass-covered plateaux in the centre of the island was a work of great difficulty.

The rock-specimens collected by Ross serve to illustrate these descriptions of the island. With the exception of two rolled pebbles (probably from the beach) of radiolarian chert and coralline limestone, they are all of volcanic material. They are mostly of phonolite, but comprise also examples of basaltic rocks, including nephelinite and limburgite, and of tuffs and agglomerates made up of fragments of both phonolites and basalts.

Phonolites.

The phonolites in appearance and structure are of various types, although in general characterised by the size and great number of the abundant phenocrysts of nepheline, as well as by the large amount of

---

[1] *The Cruise of the "Falcon."* London, Sampson Low, &c., 1887. *The Cruise of the "Alert."* London, Longmans, Green & Co., 1890.

[2] The phonolite Peak of Fernando Noronha was originally described as of granite (*Quart. Journ. Geol. Soc.* xlii, 1872, p. 43).

Digitized by Google

the pyroxenic constituent ægirine-augite. They are therefore somewhat darker and more strikingly porphyritic than the ordinary type of phonolite, and some, by decrease in the felspathic constituent and gradual replacement of the grass-green ægirine-augite by purplish augite, approach to nephelinites.

As already mentioned, the "greenstone" of the Nine-Pin Rock in Ross's account is probably phonolite and not basalt. Dr. McCormick, the surgeon on board the *Erebus*, in his book, *Voyages of Discovery in the Arctic and Antarctic Seas, &c.* (London, Sampson Low, 1884) describes on one side of the Nine-Pin Rock a dyke of "basalt," and on the other a larger one of "greenstone," thus distinguishing between the two. The large dyke of "greenstone" is stated to exhibit on its surface a singular mammiform appearance.

One of the specimens of phonolite (75355) in the collection answers precisely to this description. It is a dark greenish-brown rock with greasy lustre and splintery fracture, with a weathered surface covered with warty mammiform protuberances as described by McCormick.

Under the microscope are seen large porphyritic nephelines with small ægirine-augites and, very sparingly, sanidine and sphene in a fine-grained base of lath-shaped felspars, ægirine-augite and nepheline.

The nepheline phenocrysts are in very sharply-defined hexagonal (showing in convergent light a negative uniaxial figure) and rectangular sections: they are clear and unaltered, and include small crystals of ægirine-augite, sphene and magnetite. In one hexagonal section stages of growth are marked by a series of lines of dark inclusions parallel to the outer edges.

Sanidine is only represented amongst the phenocrysts by one or two Carlsbad twins.

The ægirine-augite is in large amount in small well-defined prismatic crystals, showing pleochroism a = grass-green; b = dull-green; c = bright brownish yellow with a tinge of red. The maximum extinction in prismatic sections does not exceed 30°. Some of the larger phenocrysts have purple centres.

Hornblende is represented by a few corroded deep brownish-red sections with the pleochroism of barkevicite or basaltic hornblende. These show signs of being partly re-absorbed, and have borders of magnetite grains, in one or two cases fringed with ægirine-augite. Small rounded patches of an aggregate of magnetite grains and reddish-brown hornblende, surrounded by a zone of ægirine-augite, are in all probability pseudomorphs after hornblende crystals.

Digitized by Google

The sphene is in sharply-defined colourless characteristic lozenge-shaped crystals.

One or two altered hexagonal sections are probably to be referred to nosean.

The groundmass, showing well-marked flow-structure, consists of felspar laths with straight extinction, needles of ægirine-augite, and nepheline in rectangular and hexagonal sections. It is rendered rather dense by dusty brown interstitial matter.

A pale green rock (No. 75349), with greasy lustre, markedly porphyritic, with large crystals (up to 5 mm. in length) of sanidine and nepheline, is in appearance more like an ordinary phonolite. It contains the same minerals as the preceding, but is much more porphyritic, the phenocrysts being more numerous, and in the case of the ægirine-augite larger, and the groundmass much finer-grained and showing no flow structure.

The pyroxenic constituent is in large amount, both as small prismatic crystals in the base and as sharply-defined phenocrysts. It consists for the most part of grass-green to yellow ægirine-augite, but some of the sections are pleochroic (purplish brown to yellow) augite, while others show purple centres with green borders, and one has a green centre and border with a purple zone between.

The section shows a coarse-grained patch of orthoclase and nepheline with prismatic ægirine-augite. Similar patches have been recorded in phonolites from Fernando Noronha, and have been regarded as fragments of the nepheline-syenite magma.[1]

A still more porphyritic type (No. 75353) shows large phenocrysts of sharply-defined nephelines and rounded, partially re-absorbed, sanidines, with smaller augites (both purple and grass-green), noseans (showing six-rayed stars of inclusion) and sphenes, in a pale brown very fine-grained base crowded with minute ægirine-augite microliths. Some of the felspar phenocrysts show very fine twin striations suggestive of anorthoclase. A phonolite from Leao, Fernando Noronha, presents very similar characters.

A specimen (No. 75348) of a somewhat camptonitic type is a pale greenish-grey rock with small vesicular cavities filled with zeolites, showing no porphyritic nepheline or felspar, but only long prismatic augites with a few larger hornblendes. Under the microscope the porphyritic augites are seen to be mainly of the purplish titaniferous kind,

[1] *Am. J. Sci.* XXXVII, 1889, p. 185.

Digitized by Google

and the hornblendes, in almost as large amount as the augites, are of the same type as in the preceding rocks, and have generally a mantle of green augite with magnetite. Nepheline is present in a few small rectangular sections much altered. Sphene and altered noseans are fairly plentiful. Apatite occurs in small hexagonal sections enclosed in the hornblende and augite. Only one phenocryst of sanidine was observed in the slide. The fine-grained groundmass consists of interlacing minute lath-shaped felspars with altered nosean and some granular augite: some clear isotropic patches are probably analcime.

This slide also contains a coarse-grained patch (about 4 mm. square) of nepheline and lath-shaped Carlsbad twins of felspar, with a little ægirine-augite.

A specimen (No. 75358) approaching more closely in structure the ordinary type of phonolite than any of the preceding, is a greenish-brown somewhat altered rock showing to the lens only small prismatic phenocrysts of sanidine. In the section besides these sanidines (in Carlsbad and Baveno twins) are one or two large altered nephelines and a little ægirine-augite. The groundmass consists of lath-shaped felspars with trachytic flow structure and much ægirine in small prismatic crystals, showing approximately straight extinction and compensating with the quartz wedge along their length ($\mathfrak{a}$—axis of indicatrix nearly coincident with the crystallographic axis c).

Phonolite-Nephelinites.

A dark greenish grey to black very compact rock (No. 75346), showing porphyritic nephelines and an occasional large sanidine, has characters intermediate between a phonolite and a nephelinite. It consists of phenocrysts of purplish-green augite in large amount, a little basaltic hornblende similar to that in the preceding rocks, and a few large nephelines with sphene and apatite in a base composed of altered nephelines with small prismatic ægirine-augites and some felspar laths. The nephelines, unlike those in the phonolites previously described, are for the most part corroded and rounded (in some cases presenting perfectly circular outlines), and are often crowded with gas-pores.

Hornblende, mostly nearly re-absorbed, is not present in large amount, but the section contains dark patches (in one case over $\frac{1}{2}$-in. square), consisting of an aggregate of purplish and green augite, deep brownish-red pleochroic hornblende, much opaque iron-ore (magnetite?), with apatite and sphene, which may represent original hornblende crystals

Digitized by Google

one of these patches had a roughly crystalline outline with two faces meeting at an angle of about 124°.

A specimen (No. 75341) of a dark-grey to deep reddish-brown compact rock showing porphyritic crystals of augite and hornblende, generally small, but in the case of the hornblende sometimes reaching 5 mm. in length, shows a closer approximation to a nephelinite. It consists of a base of nepheline in large plates and indefinite crystals with only a little felspar, forming a sort of paste in which are distributed augites in large amount, hornblendes, sphene and apatite, with some magnetite and ilmenite. The augites and hornblendes have similar characters to those of the preceding rock. The pleochroism of the hornblende was similar to that of barkevicite, viz. a = pale yellowish brown; b = deep reddish-brown; c = deep brown, nearly opaque. Prismatic sections showing only one cleavage gave extinctions as high as 13°, and octagonal sections showed the two cleavages inclined at an angle of about 124°. The apatite was so crowded with gas-pores as to be nearly opaque.

Limburgites.

These dense black basaltic-looking rocks (Nos. 75352 and 75333) are seen under the microscope to consist of small porphyritic augites, and in smaller amount of olivine, with magnetite, in a dense brownish-red glass, containing microliths of augite. The augite phenocrysts are very pale purple, generally with a green centre. One or two of the larger crystals had a centre consisting of an aggregate of magnetite grains and a deep brown hornblende, and are the result probably of the re-absorption of an original hornblende crystal. One or two rounded grains of reddish-brown basaltic hornblende are present in the slide. The augite and hornblende phenocrysts are therefore somewhat similar in character to those in the preceding nephelinites.

The olivine is clear and fresh, and occurs generally in long prismatic crystals. One or two corroded grains and irregular crystals of olivine have attachments of augite and hornblende on the corners and filling up cracks.

A patch of grass-green ægirine-augite grains with sphene has probably been derived from the phonolites.

Another specimen (No. 75364) of dense black basaltic rock, with a rough glassy surface, shows in section the passage (from the surface inwards) from a brown glass, with augite microliths, in which are distributed crystals of clear fresh olivine in large amount, to a rock consisting of porphyritic olivines in a dense base almost opaque from separation of

Digitized by Google

magnetite and crowded with radiating groups of small pale purple augites. In the intermediate part the augite microliths are surrounded by deep halos of magnetite, and the intervening glass is a clear pale yellow.

Volcanic Agglomerate.

A specimen of volcanic agglomerate (No. 75360) contains, besides fragments of nepheline, felspar, ægirine-augite, and phonolite, also fragments of more basic rocks, some of them showing long prismatic crystals of basaltic hornblende, and presenting a structure very similar to that of the dyke rocks from Fernando Noronha, which were described by the author (*Min. Mag.* XI, 1897, 171) as related to the monchiquites of Rosenbusch.

The only specimens not of volcanic origin were fragments, probably from the beach, of *coralline limestone* containing pebbles of phonolite, and a rounded pebble of *radiolarian chert*.

The characters of these rocks, as well as many of the geological features of the island, such as the remarkable peaks of phonolite associated with basaltic lavas, suggest analogies between Trinidad and the island of Fernando Noronha off the coast of Brazil, a thousand miles to the north, so that it appears possible that the two islands owe their origin to a very similar, if not contemporaneous, volcanic outbreak.

In Fernando Noronha, as Branner[1] states, the original lofty central portion has been denuded away until only the great Peak and its smaller companions remain to suggest the formal elevation of the group. In Trinidad the disintegrating agents have not effected so radical a change. The lofty inaccessible peaks of the central portion still remain, but Knight's account suggests that the time when these will have been levelled cannot be very far distant, for denudation appears to be going on at a very rapid rate, and enormous landslips are of frequent occurrence.

---

[1] *Am. J. Sci.* XXXVII, 1889, p. 146.

Digitized by Google

On some remarkable composite crystals of copper pyrites from Cornwall.

By Professor W. J. Lewis, M.A., and A. L. Hall, B.A.

[Read January 23rd, 1900.]

During a recent visit to Cornwall the attention of Professor Lewis was directed by Mr. James Wickett to some composite crystals of copper pyrites recently found in one of the deep mines in the neighbourhood of Redruth. On the specimens acquired by the Cambridge Museum about thirty crystals show this composite growth, which causes the crystals to resemble ill-developed pentagonal dodecahedra of iron pyrites. Many of them are much tarnished, and some show purple and blue colours due to thin films: and they are deposited together with small brilliant crystals ({100} and {111}) of hæmatite on a matrix of chalybite, which at the surface is developed in minute lenticular crystals.

Simple crystals.

The habit of most of the crystals is notably sphenoidal, owing to the predominance of two forms, which are in some cases a very obtuse sphenoid and a very acute one; in other cases the obtuse sphenoid is replaced by the pinakoid or by the pinakoid alternating with the faces of an obtuse sphenoid. The obtuse sphenoid is either $l=\kappa\{114\}$, or $\lambda=\kappa\{229\}$, or $\gamma=\kappa\{115\}$, or $\beta=\kappa\{118\}$. The acute sphenoid is one of the following: $\rho=\kappa\{553\}$, $r=\kappa\{332\}$, $t=\kappa\{221\}$, $f=\kappa\{552\}$, $u=\kappa\{441\}$, $F=\kappa\{551\}$, $T=\kappa\{22\bar{1}\}$.

The faces of the above sphenoids, of the pinakoid $c\{001\}$, and in many cases those of the prism $m\{110\}$ are deeply striated in a direction parallel to the edges in which faces in a vertical zone intersect. This striation has rendered it very difficult to determine the symbols of the forms. Another difficulty was likewise encountered, for measurements between tautozonal faces on opposite sides of the principal axis often differed by 4° or 5°; and it was occasionally observed that on one side the face (441) or (551) is largely developed, whilst on the other side the face $(\bar{1}\bar{1}0)$ is the conspicuous one. The sphenoid $o=\kappa\{11\bar{1}\}$ is generally present, but [illegible] faces are always very small; they are, however, fairly free from striæ, [illegible]measurements from them to faces in adjacent vertical zones have

Digitized by Google

served to check the determination of the symbol of these latter faces. The sphenoid $T=\kappa\{22\bar{1}\}$ is often present, but the faces are in all cases very dull.

Faces of one or both of the pyramids $e\{101\}$, $z\{201\}$ often occur as small triangles modifying the coigns on the horizontal edges in which the faces of the obtuse sphenoid or pinakoid meet the faces of the acute sphenoid. The faces z are striated each in a direction which seems to be parallel to the edge of intersection with an adjacent face (111); each face e in a direction parallel to the adjacent face $(1\bar{1}1)$. The faces of these forms are usually bright, but the striæ have much interfered with their usefulness in determining the symbols of particular faces or in confirming the twin-law.

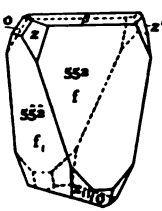


FIG. 1.

Fig. 1 represents a very small crystal on which the forms $\beta=\kappa\{118\}$, $f=\kappa\{552\}$, $o=\kappa\{1\bar{1}1\}$, $z=\{201\}$ were definitely determined. Close inspection of the coigns at which the faces z appear reveals the presence of two or three additional forms, the faces of which are too striated to admit of accurate measurement. Measurements of the angles between faces of one of these forms and those of z accord fairly well with the form being $\kappa\{825\}$; the faces of another form belong to $e\{101\}$. The faces of these two forms, being very subordinate, have been omitted in the drawing. The faces z are striated parallel to the edges of intersection with the adjacent faces of $\kappa\{825\}$.

A second crystal measured shows the forms $\lambda=\kappa\{229\}$, $\gamma=\kappa\{332\}$, $m\{110\}$, $T=\kappa\{22\bar{1}\}$. The coigns at which faces λ, r and T meet are modified by well developed faces σ, which are striated in the same way as the faces z in the first crystal. The measurements between homologous faces σ do not agree with those of $e\{101\}$; and the form nearly accords with $\{1, 12, 12\}$. The same displacement of the faces from the position of those of the pyramid e was also observed on one of the twin-crystals described further on.

In a third crystal the faces of the pinakoid $c\{001\}$ and of the sphenoid $F=\kappa\{551\}$ are largely developed; those of the sphenoid $\lambda=\kappa\{229\}$ are narrow planes modifying the obtuse edges $[c\ F]$. The faces of the sphenoid $o=\kappa\{1\bar{1}1\}$, and of the pyramid $e\{011\}$ are very small. The symbols of the faces λ are deduced from measurements of the angles $o\lambda\lambda$; for the faces λ and of the pinakoid are much striated parallel to their common edge. The face c in this and other crystals, on which the inclination to other faces was measured, seems generally to be a good deal

Digitized by Google

displaced. Thus, $c\wedge\lambda'(\bar{2}\bar{2}9)$ was found to be 16°4′, and $c\wedge\lambda(229)$ to be 18°48′. That it is the face c which is displaced was shown by measurement of the angles $o\lambda$ and $o\lambda'$; for $o\lambda = 56°7'$ and $o\lambda' = 56°20'$.

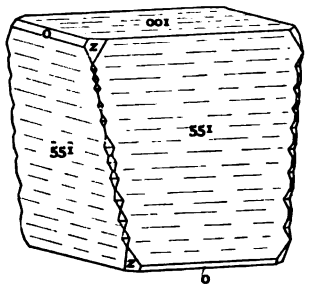


Fig. 2.

Fig. 2 represents a crystal having a somewhat cubic habit. The forms present are, according to measurements made with a contact-goniometer, taken to be $\kappa\{551\}$, $\{001\}$, $\{201\}$, $\{100\}$. The faces o and z are very small; and pairs of the latter alternate with faces of the tetragonal prism $\{100\}$ in such a way as to give the appearance of a deeply furrowed face which truncates the slanting edges of the acute sphenoid. The relative dimensions of these alternating faces to those of the sphenoid are much exaggerated in the drawing. In some crystals of this habit the sphenoid seems to be $\kappa\{441\}$ or $\kappa\{552\}$, and occasionally the faces of the prism $\{110\}$ are also present. In a few cases the crystals have an irregular development, owing to the fact that the predominant faces consist of two or three faces of the acute sphenoid associated with one or two faces of the prism $\{110\}$. Thus we get the crystal sometimes bounded by the pinakoid $\{001\}$, a pair of opposite faces of the sphenoid, such as $(\bar{5}5\bar{2})$, $(5\bar{5}\bar{2})$, and a pair of opposite prism-faces (110), $(\bar{1}\,\bar{1}0)$. A crystal of this type is shown in Fig. 3, which gives approximately the relative sizes of the faces. The crystal is an acute wedge which is much elongated along the edge of intersection of the two predominant faces of the sphenoid $\kappa\{552\}$.

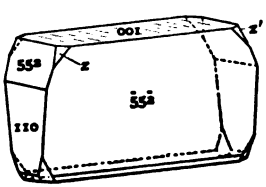


Fig. 3.

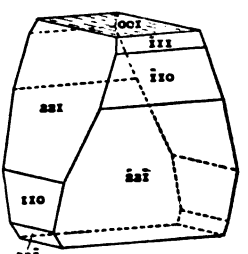


Fig. 4.

Fig. 4 represents in equable and normal development the general habit resulting from the combination of forms $\{001\}$, $\kappa\{221\}$, $\{110\}$, $\kappa\{11\bar{1}\}$. But the forms are commonly unequably developed; and, as illustrated by Fig. 8, the faces of $\kappa\{221\}$ are sometimes interrupted, and a prism-face (110) is interposed between two portions of the same face (221).

Digitized by Google

Twin-crystals.

The twin-axis is the normal to a face of the sphenoid $o = \kappa\{1\bar{1}1\}$.

The peculiar resemblance to iron pyrites of the most remarkable of the twins arises from the great development of the obtuse sphenoid. In the twins of this character the individuals are mostly in juxtaposition; but the combination-surface is rarely a definite plane, and there is a certain amount of interlocking, and in many cases portions of one individual protrude beyond the other. The depth of striation also causes a considerable irregularity in the edges common to the two individuals. If a crystal like one of those represented in Figs. 1 and 4 is bisected by a central plane perpendicular to the twin-axis, the edges in which the plane of section meets the faces will not be all congruent after one portion has been turned through 180° about the twin-axis. Supposing the normal $(1\bar{1}1)$ to be the twin-axis, the two prism-faces (110) and $(\bar{1}\,\bar{1}0)$ which are parallel to it change places, and these faces will be co-planar in the twin. Again, the faces in the zone $[001, 1\bar{1}1]$, which includes the face $o(1\bar{1}1)$, are tautozonal in the twin; and any pair of such faces which meet intersect in a line parallel to the edges of the zone. Thus, in the somewhat idealised doublet shown in Fig. 5, the face $T(\bar{2}21)$ intersects $i_{,}(1\bar{1}\bar{4})$ in a re-entrant edge parallel to the edge $[l_{,}l_{,,}]$. In this doublet the two faces 221 and $(\bar{2}\bar{2}\bar{1})$, which belong to the complementary sphenoids $\kappa\{221\}$ and $\kappa\{22\bar{1}\}$, are represented as equably developed on opposite sides of the combination-plane, which has been taken to be $(1\bar{1}1)$ perpendicular to the twin-axis; and this is very nearly the case in the quartet of which three individuals are shown in Fig. 6. In some cases the individuals are juxtaposed approximately along a plane which belongs to a different form in each individual. Thus in several of the twins the combination-plane is $t(221)$ of one individual and $c(001)$ of the other. In twins of this character the individual having c for combination-plane is usually smaller than the other, and is often reduced to such small dimensions that it looks much like a limpet deposited on a relatively large (221) face of the large individual.

In other cases the one individual completely penetrates the other, the imbedded individual being always small compared with the other. An instance of this case of the twin is shown in Fig. 8, where a striated face $c_{,}$ appears as an irregular patch in the face $t(221)$, with which $c_{,}$ is practically co-planar; the theoretical angle between the two being 1°4′. On the face adjacent to t the imbedded twin-individual appears as a wedge inserted in the crystal. Occasionally the patch forms, as it were, an

Digitized by Google

island in the face t: such patches are very noticeable, for the striæ on c, are at right angles to those on the face t and to those on the face c which is inclined to the patch at an angle of 71°20′.

The twin-law was established by measurements of the angles $l \wedge l_{,}$, $l' \wedge l_{,}$, $l \wedge l_{,,}$, $l' \wedge l_{,,}$, $o \wedge o_{,}$, $o \wedge o_{,,}$; and of a zone $[l_{,,} l_{,} l'\bar{1}]$, common to two individuals, which are united to a middle one about the homologous twin-axes $1\bar{1}1$ and $\bar{1}11$ respectively. The measurements in this zone were:—$t_{,,} l_{,,} = 50°21'$, $l_{,,} l_{,} = 38°3'$, $l'_{,} 1 = 103°25'$, $l' 1 = 38°5'$, $1\,t = 50°13'$, $1m = 72°12'$. The face l being (114), the twin-law gives $l_{,} \wedge l' = 104°16'$, and t being (221), $t_{,,} \wedge t = 283°12'$, whilst the sum of the angles from $t_{,,}$ to t is 280°7′, and again $t_{,,} \wedge m = 302°56'$, measured 302°6′. The measured angle $l \wedge l_{,} = 114 \wedge (1\bar{1}\bar{4})$ was found to be 55°0′, and $l' \wedge 1' = \bar{1}\bar{1}4 \wedge (1\bar{1}\bar{4})$ to be 54°43′, whilst the computed value is 54°34′. The measured angle $l \wedge l_{,,} = 114 \wedge (\bar{1}1\bar{4})$ is 90°8′, $l' \wedge l_{,,} = \bar{1}\bar{1}4 \wedge (\bar{1}1\bar{4})$ is 90°1′; the computed value being 90°30′. Further, $o \wedge o_{,} = 1\bar{1}1 \wedge (\bar{1}\bar{1}\bar{1}) = 109°19'$, $o \wedge o_{,,} = 1\bar{1}1 \wedge (11\bar{1}) = 110°25'$; the computed value being 109°54′.

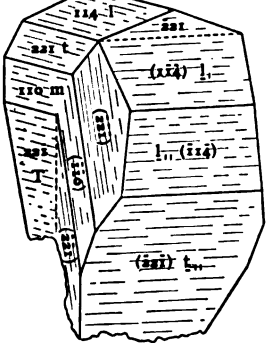


Fig. 5.

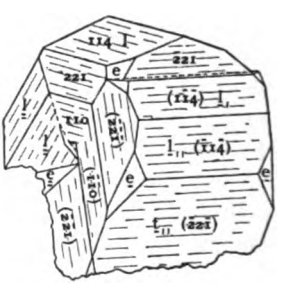


Fig. 6.

Fig. 6 represents a twin in which three unequal individuals are united to a central one about homologous axes. The first individual (that to the right) is twinned to the upright one about the normal $(1\bar{1}1)$; the second (that to the front) about the normal $(11\bar{1})$; and the third, which is very small and has its faces l tautozonal with those of the individual to the right, is twinned to the upright one about $(\bar{1}11)$.

Two individuals are frequently united to a larger one in the manner just described for the first and third individuals; *i.e.* the latter are twinned

Digitized by Google

to the central individuals about the normals to faces $(1\bar{1}1)$ and $(\bar{1}11)$, which are tautozonal with (001) of the larger crystal. The measurements in such a zone have been already given.

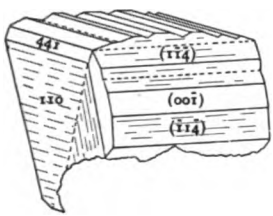


FIG. 7.

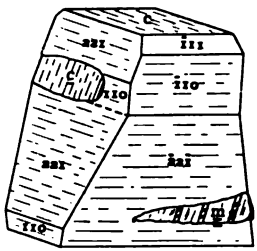


FIG. 8.

Fig. 7 shows an instance of a doublet in which but few forms are present. The pinakoids are largely developed, but very rough. They are mainly composed of ridges formed by alternating faces of an obtuse sphenoid, which may be $\kappa\{118\}$, or $\kappa\{114\}$, &c. The acute sphenoid has been taken to be $\kappa\{441\}$, and the composite face shown is apparently (110); but the crystal has only been measured by a contact goniometer, for the faces are rough, dull and much tarnished. This twin represents an intermediate stage between those of the type shown in Figs. 5 and 6 and those, like Fig. 8, in which the twin is only shown by a patch imbedded in a face t (221) of an apparently simple crystal.

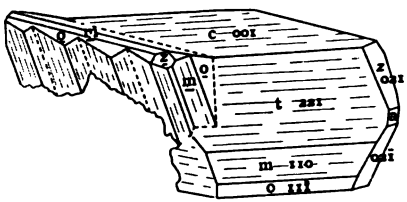


FIG. 9.

Fig. 9 shows a twin of a different habit. This twin differs so much from all the others that we at first thought we had to deal with two different laws; but measurements easily established that $(1\bar{1}1)$ is the twin-face. The drawing shows with fair approximation the relative dimensions of the faces.

A second wedge of inserted matter is shown on the face $(\bar{2}2\bar{1})$ of Fig. 8 protruding into the crystal. At the back of the crystal a horizontally striated patch is observed; and the patch consists of a face c, which seems co-planar with the face $t'(\bar{2}\bar{2}1)$. If the faces t'' and c were

Digitized by Google

approximately co-planar, the striæ on the latter should be in a vertical plane; and it seemed as if the inserted matter had further undergone a quarter-revolution about its principal axis. Careful examination convinced the authors that the appearance of the two faces being co-planar was deceptive, and that the inserted matter has been turned through 180° about the normal $(11\bar{1})$. This is shown by the fact that the coarse markings on m are practically parallel to the face $t(221)$; and the face c to which they are parallel is therefore really parallel to t, and not to t'.

In drawing asymmetric twins such as those which we have described there is some difficulty in determining the directions of the edges in which non-homologous faces meet. Such edges are often most easily found by taking approximate values for the parameters which give rational indices to the faces of the rotated crystal, when the latter is referred to the axes of the fixed individual. Mr. R. W. H. T. Hudson,[1] B.A., of St. John's College, has been good enough to determine a formula which gives the position of a face-normal after a rotation of 180° about any twin-axis, and also a more generalised one which applies when the angle of rotation is θ. In applying his general formulæ to the twins of copper pyrites, the crystal is taken to have rectangular axes and equal parameters; *i.e.* to be, as far as computations are concerned, cubic. The twin-axis being now taken to be $(1\bar{1}1)$, and $(h_1k_1l_1)$ being the symbol of a face or normal which is (hkl) before a semi-revolution about $(1\bar{1}1)$, then the new indices are given by the equations:—

$$\left.\begin{aligned} 3h_1 &= -3h+2(h-k+l),\\ 3k_1 &= -3k-2(h-k+l),\\ 3l_1 &= -3l+2(h-k+l), \end{aligned}\right\} \ldots\ldots (1)$$

In the case of copper pyrites the new symbol of any face (hkl) can be also easily found from the above-mentioned approximation to the parameter c, and the following two relations:—(1) That the face in its new position is in a zone with o and its original position; (2) That its inclination to o remains unchanged. Hence (hkl) being the original face, and $(h_1k_1l_1)$ its symbol after a semi-revolution about $(1\bar{1}1)$, we have the equations:—

$$\begin{vmatrix} h_1 & k_1 & l_1 \\ 1 & \bar{1} & 1 \\ h & k & l \end{vmatrix} = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2);$$

[1] Mr. Hudson's formulæ are given in the *Mineralogical Magazine*, XII, p. 345, 1900.

Digitized by Google

$$\text{Cos } oP = \frac{h-k+l}{\sqrt{3}\sqrt{h^2+k^2+l^2}} = \frac{h_1-k_1+l_1}{\sqrt{3}\sqrt{h_1^2+k_1^2+l_1^2}} \quad \ldots\ldots \quad \ldots\ldots\ldots\ldots (3).$$

By substituting in (3) the value obtained from (2) of one of the unknown indices—k_1 (say)—in terms of the two others, a quadratic equation in the two indices h_1, l_1 is found. The roots of this equation are easily obtained; for it must break up into two linear factors, one of which must be $h_1 l - h l_1$. Thus for $l_{,}(1\bar{1}\,\bar{4})$ equation (2) gives—

$$h_1 + k_1 = 0 \quad \ldots \quad \ldots \quad ;$$

and equation (3) becomes—

$$(4h_1 + l_1)\,(8h_1 + 7l_1) = 0.$$

Hence the face in its new position has the symbol $(\bar{7}78)$.

The following table gives the position after a semi-revolution about $o(1\bar{1}1)$ of a face having the symbol given in the second column:—

	Originally.	After rotation.		Originally.	After rotation.
$l_{,,}$	$\bar{1}1\bar{4}$ ...	*$\bar{1}10$*	$o_{,,}$	$\bar{1}\bar{1}\bar{1}$ ...	*151*
$c_{,}$	$00\bar{1}$ ...	*$\bar{2}21$*	$A_{,}$	010 ...	*212*
$l_{,}$	$1\bar{1}\bar{4}$ ...	*$\bar{7}78$*	e	101 ...	*$1\bar{4}1$*
$t_{,}$	$2\bar{2}\bar{1}$ ...	*001*	m	110 ...	*$\bar{1}\bar{1}0$*
m	$1\bar{1}0$ ...	*$1\bar{1}4$*	t	221 ...	*$4\bar{8}\bar{1}$*
			l	114 ..	*$5\bar{1}\bar{1}\bar{4}$*

The principal angles measured on the crystals are given in the following table: the striation and tarnish of the faces render it impossible to get really trustworthy measurements.

Angles measured.		No. of Observations.	Extremes.	Mean.	Calculated.
oc	111 ∧ 001	11	53°17′ — 54°45′	54° 8′	54°20′
ll'	114 ,, $\bar{1}\bar{1}4$	6	37 55 — 39 56	38 31	38 25
$\lambda\lambda'$	229 ,, $\bar{2}\bar{2}9$	8	32 17 — 36 10	34 24	34 24
$\gamma\gamma'$	115 ,, $\bar{1}\bar{1}5$	2	29 23 — 29 53	29 38	31 8
$\beta\beta'$	118 ,, $\bar{1}\bar{1}8$	1	..	19 31	19 46
$\pi\pi'$	332 ,, $\bar{3}\bar{3}2$	2	126 59 —128 4	127 32	128 52
cr	001 ,, 332	6	62 53 — 65 0	63 49	64 26
$\rho\rho'$	553 ,, $\bar{5}\bar{5}3$	1	..	131 57	133 24
$c\rho$	001 ,, 553	4	65 35 — 67 48	66 48	66 4
tt'	221 ,, $\bar{2}\bar{2}1$	1	..	138 54	140 32
ct	001 ,, 221	8	69 15 — 71 42	70 20	70 16

Digitized by Google

Angles Measured.	No. of Observations.	Extremes.	Mean.	Calculated.
ff' 552 ∧ $\bar{5}\bar{5}2$	1	..	147°22′	147°58′
cf 001 ,, 552	2	72°56′ — 75°45′	74 20	73 59
cF 001 ,, 551	1	..	81 6	81 50
c,u 00$\bar{1}$,, 4$\bar{4}\bar{1}$	1	..	101 37	100 10
cm 001 ,, 110	1	..	90 32	90 0
om 1$\bar{1}$1 ,, 1$\bar{1}$0	7	35 13 — 37 44	36 39	35 40
mT 110 ,, 22$\bar{1}$	1	..	22 25	19 44
lρ 114 ,, 553	3	47 16 — 48 41	48 2	47 30
tt, 221 ,, 2$\bar{2}\bar{1}$	1	..	97 1	96 33
ee' 101 ,, 011	1	..	59 27	59 30
ee'' 101 ,, $\bar{1}$01	1	..	89 50	89 9
ae 100 ,, 101	1	..	45 45	45 25
zz' 201 ,, 0$\bar{2}$1	6	76 30 — 79 43	78 11	78 11
os 1$\bar{1}$1 ,, 201	5	35 44 — 39 50	38 19	39 6
mz 1$\bar{1}$0 ,, 201	1	..	50 38	50 54
az 100 ,, 201	2	27 26 — 27 33	27 29	26 54
zz'' 201 ,, $\bar{2}$01	1	..	125 11	126 11
el 101 ,, 114	4	31 17 — 33 48	32 3	33 17
el' 101 ,, $\bar{1}\bar{1}$4	3	59 10 — 60 2	59 44	59 22
ξξ' 825 ,, 285	1	..	51 59	52 0
oλ 1$\bar{1}$1 ,, 229	2	56 7 — 56 20	56 13	56 9
oe 1$\bar{1}$1 ,, 101	1	..	35 45	35 4
oe' 1$\bar{1}$1 ,, 011	1	..	89 14	89 18
or 1$\bar{1}$1 ,, 332	1	..	76 16	75 26
er 101 ,, 332	1	..	41 46	40 58
σσ' 1,12,12 ∧ 12,1,12	2	53 37 — 55 24	54 30	54 2
σσ'' 1,12,12 ,, $\bar{1}$,$\bar{1}\bar{2}$,12	2	89 25 — 89 50	89 38	89 20
σσ''' 1,12,12 ,, $\bar{1}\bar{2}$,$\bar{1}$,12	4	63 0 — 65 43	63 52	64 54
mσ 110 ∧ 1,12,12	1	..	57 29	57 33
oo,, 1$\bar{1}$1 ,, (11$\bar{1}$)	1	..	109 19	109 52
oo, 1$\bar{1}$1 ,, ($\bar{1}\bar{1}$1)	1	..	110 25	
ll, 114 ,, (1$\bar{1}\bar{4}$)	1	..	55 0	54 34
l'l, $\bar{1}\bar{1}$4 ,, (1$\bar{1}\bar{4}$)	1	..	54 43	
ll,, 114 ,, ($\bar{1}$1$\bar{4}$)	1	..	90 8	90 30
l'l,, $\bar{1}\bar{1}$4 ,, ($\bar{1}$1$\bar{4}$)	1	..	90 1	

Digitized by Google

On Grassmann's method of axial representation, and its application to the solution of certain crystallographic problems.

By W. J. Lewis, M.A.,

Professor of Mineralogy in the University of Cambridge.

[Read April 3rd, 1900.]

GRASSMANN, in his Memoir, *Zur physischen Krystallographie und geometrischen Combinationslehre*, published in 1829, referred a crystal to three face-normals—*rays*—as axes of reference; the parameters being the edges along the axes of a parallelepiped having for diagonal a definite length of a known normal which is not co-planar with any pair of the axial rays. Any other normal is then represented as the diagonal of a similarly formed parallelepiped having for its edges along the axes lengths which are rational multiples of the parameters. Grassmann gave no formulæ for finding in general the indices of face-normals from measurements of the angles on the crystal; nor for determining the angles from the crystal-elements and indices. Frankenheim (Crelle's *Journal f. Mathematik*, VIII, p. 178, 1832) gives an expression for the cosine of the angle between any two rays, but his expression is not in a form such as is now usually adopted. Miller, in his memoir on the method (*Proc. Camb. Phil. Soc.* II, p. 75, 1868) limited himself to a few general problems relating to zones. The space which could be spared to the subject in my *Treatise on Crystallography*, 1899, only allowed me to give the relation connecting the ray-parameters with those of a crystal referred to zone-axes. But the inclination of any ray to the reference-rays and to any other ray can be easily found by the process adopted in Chapter XIX, Arts. 9, 10, 11, 13 and 14 of my *Treatise* for the similar relations connecting the direction of a line with axes which are edges of the crystal. The relations obtained when the crystal is referred to axial rays are more immediately applicable to the angles found by goniometric measurement, and are in many respects simpler than the relations given in the above mentioned articles. As, further, Grassmann's axial representation gives many elegant expressions applicable to the solution of problems which occur in the determination of the face-symbols and angles of crystals, I have thought that it may prove useful to establish some of the principal relations.

Digitized by Google

We shall throughout assume that the same three faces are selected to give the axial system, the axial rays being parallel to their normals, and the ordinary axes to their edges of intersection. We shall take Ox, Oy and Oz to be the rays which are, respectively, perpendicular to the faces (100), (010) and (001). We shall denote by OG the parametral ray (111), and shall suppose it to be perpendicular to the face (111) referred to zone-axes. We shall denote the ray-parameters by a, b, c, and the angles between the axial rays by α, β, γ. The corresponding parameters and angles, when the crystal is referred to zone-axes, will be denoted by a, b, c, α_1, β_1, γ_1. Any ray (hkl) of the crystal is then given by the equations—

$$\frac{x}{ha}=\frac{y}{kb}=\frac{z}{lc} \quad \ldots\ldots\ldots\

$$OP = OL\cos\lambda + LF\cos\mu + FP\cos\nu$$
$$= ha\cos\lambda + kb\cos\mu + lc\cos\nu \ldots\ldots (4).$$

Again, taking the orthogonal projections of OP and of the above three edges of the parallelepiped on each of the axial rays in turn, we obtain the following equations:—

$$\left.\begin{aligned} OP\cos\lambda &= OL + LF\cos\gamma + FP\cos\beta = ha + kb\cos\gamma + lc\cos\beta \\ OP\cos\mu &= ha\cos\gamma + kb + lc\cos\alpha \\ OP\cos\nu &= ha\cos\beta + kb\cos\alpha + lc \end{aligned}\right\} \ldots (5).$$

Multiply both sides of (4) by OP and introduce the values of $OP\cos\lambda$, &c., from (5). We then have—

$$OP^2 = ha(ha + kb\cos\gamma + lc\cos\beta) + kb(ha\cos\gamma + kb + lc\cos\alpha)$$
$$+ lc(ha\cos\beta + kb\cos\alpha + lc) = \Sigma h^2a^2 + 2\Sigma klbc\cos\alpha \ldots\ldots\ldots (6).$$

Prop. 2. To find the direction-cosines of any ray, and the relation which exists between them and the angles between the axial rays.

The direction-cosines are found by introducing in (5) the value of OP given in (6). They are, therefore,—

$$\left.\begin{aligned} \cos\lambda &= \frac{ha + kb\cos\gamma + lc\cos\beta}{\sqrt{\Sigma h^2a^2 + 2\,\Sigma klbc\cos\alpha}} \\ \cos\mu &= \frac{ha\cos\gamma + kb + lc\cos\alpha}{\sqrt{\Sigma h^2a^2 + 2\,\Sigma klbc\cos\alpha}} \\ \cos\nu &= \frac{ha\cos\beta + kb\cos\alpha + lc}{\sqrt{\Sigma h^2a^2 + 2\,\Sigma klbc\cos\alpha}} \end{aligned}\right\} \ldots\ldots (7).$$

Equations (4) and (5) hold for any ray. Eliminating, therefore, OP, ha, kb, lc from the four equations, we obtain the relation which holds between the direction-cosines: it is—

$$\Delta_1 = \begin{vmatrix} 1 & \cos\lambda & \cos\mu & \cos\nu \\ \cos\lambda & 1 & \cos\gamma & \cos\beta \\ \cos\mu & \cos\gamma & 1 & \cos\alpha \\ \cos\nu & \cos\beta & \cos\alpha & 1 \end{vmatrix} = 0 \ldots (8).$$

Prop. 3. To find expressions for the indices of any ray in terms of the angles which it makes with the axial rays.

Solving equations (5) for ha, kb, lc, we have—

$$ha \div \begin{vmatrix} \cos\lambda & \cos\gamma & \cos\beta \\ \cos\mu & 1 & \cos\alpha \\ \cos\nu & \cos\alpha & 1 \end{vmatrix} = kb \div \begin{vmatrix} 1 & \cos\lambda & \cos\beta \\ \cos\gamma & \cos\mu & \cos\alpha \\ \cos\beta & \cos\nu & 1 \end{vmatrix}$$

$$= lc \div \begin{vmatrix} 1 & \cos\beta & \cos\lambda \\ \cos\gamma & 1 & \cos\mu \\ \cos\beta & \cos\alpha & \cos\nu \end{vmatrix} = OP \div \begin{vmatrix} 1 & \cos\gamma & \cos\beta \\ \cos\gamma & 1 & \cos\alpha \\ \cos\beta & \cos\alpha & 1 \end{vmatrix} \ldots (9).$$

Digitized by Google

Again, if the value of OP given in (4) be introduced into the equations (5), we obtain the following equations, which may be sometimes useful :

$$\left.\begin{aligned} ha\sin^2\lambda+kb(\cos\gamma-\cos\lambda\cos\mu)+lc(\cos\beta-\cos\lambda\cos\mu)&=0\\ ha(\cos\gamma-\cos\lambda\cos\mu)+kb\sin^2\mu+lc(\cos\alpha-\cos\mu\cos\nu)&=0\\ ha(\cos\beta-\cos\lambda\cos\nu)+kb(\cos\alpha-\cos\mu\cos\nu)+lc\sin^2\nu&=0 \end{aligned}\right\}\ldots(10).$$

Prop. 4. To find the equation of the plane perpendicular to a ray (hkl), *i.e.* of the face (hkl).

Suppose the plane to pass through the point P, which is the extremity of the diagonal of the parallelepiped having for edges ha, kb, lc; and let the ray make the angles λ, μ, ν with the axial rays.

The sum of the orthogonal projection on OP of the coordinates x, y, z of any point which lies in the plane is equal to OP.

$$\therefore\ OP=x\cos\lambda+y\cos\mu+z\cos\nu.$$

Introducing the values of $\cos\lambda$, $\cos\mu$, $\cos\nu$ from (5) and the value of OP^2 from (6), we have—

$$(x-ha)\,(ha+kb\cos\lambda+lc\cos\beta)+(y-kb)\,(ha\cos\gamma+kb+lc\cos\alpha)+(z-lc)\,(ha\cos\beta+kb\cos\alpha+lc)=0\ \ldots\ldots\ (11).$$

The parallel plane through the origin is—

$$x(ha+kb\cos\gamma+lc\cos\beta)+y(ha\cos\gamma+kb+lc\cos\alpha)+z(ha\cos\beta+kb\cos\alpha+lc)=0\ldots\ldots\ldots(12).$$

Prop. 5. To find the angle ϕ between any two rays (hkl) and $(h_1k_1l_1)$.

Let OP in Fig. 1 be the ray (hkl), and let its inclination to the axial rays be λ, μ, ν. Then the relations established in the preceding propositions hold for it. Suppose the ray $(h_1k_1l_1)$ to be given by the diagonal OP_1 of a similar parallelepiped, and its direction-angles to be λ_1, μ_1, ν_1. Then the orthogonal projection of OP on OP_1 must be equal to the sum of the projections of the edges OL, LF, FP on OP_1.

$$\begin{aligned}\text{Hence, } OP\cos\phi&=OL\cos\lambda_1+LF\cos\mu_1+FP\cos\nu_1\\&=ha\cos\lambda_1+kb\cos\mu_1+lc\cos\nu_1\ldots\ldots(13).\end{aligned}$$

But $\cos\lambda_1$, $\cos\mu_1$, $\cos\nu_1$, OP_1 are connected together by equations similar to those given in (5). Multiplying both sides of (13) by OP_1, and replacing $OP_1\cos\lambda_1$, &c., by their equivalents, we have—

$$OP.OP_1\cos\phi=ha(h_1a+k_1b\cos\gamma+l_1c\cos\beta)+kb(h_1a\cos\gamma+k_1b+l_1c\cos\alpha)+lc(h_1a\cos\beta+k_1b\cos\alpha+l_1c).$$

Hence—

$$\cos\phi=\frac{\Sigma hh_1a^2+\Sigma bc(kl_1+lk_1)\cos\alpha}{\sqrt{\Sigma h^2a^2+2\Sigma klbc\cos\alpha}\ \sqrt{\Sigma h_1^2a^2+2\Sigma k_1l_1bc\cos\alpha}}\ldots\ldots(14).$$

Digitized by Google

This expression is simpler and more easily computed than either of the expressions (44) and (47) of pages 569 and 570 of my *Treatise on Crystallography*. It can also be easily transformed into either of them by the relations (2). Thus to get (47) we need only substitute for a, b, c from (2), when we have—

$$\text{Cos}\,\phi = \frac{\Sigma\frac{hh_1}{a^2}\sin^2\alpha + \Sigma\frac{kl_1+lk_1}{bc}\sin\beta\sin\gamma\cos\alpha}{\sqrt{\Sigma\frac{h^2}{a^2}\sin^2\alpha + 2\Sigma\frac{kl}{bc}\sin\beta\sin\gamma\cos\alpha}\sqrt{\Sigma\frac{h_1^2}{a^2}\sin^2\alpha + 2\Sigma\frac{k_1l_1}{bc}\sin\beta\sin\gamma\cos\alpha}}$$

Equation (44) is found by a similar substitution from (2*), and the relations of a spherical triangle—

$$\text{Cos}\alpha = \cos\beta\cos\gamma + \sin\beta\sin\gamma\cos(A = \pi - \alpha_1),\ \&c.$$

We shall now show how this method can be applied to the solution of crystallographic problems. Thus let us take an anorthic crystal, and let it be required to find the linear elements from a knowledge of some of the angles. Adopting the letters and notation of page 161 of my *Treatise*, let us suppose the zone $[BL C] = [010, 001]$ to be known. Introducing the indices 0,1,1 of L into the first and second equations of (7), we have—

$$\cos(AL = 100 \wedge 011) = \frac{b\cos\gamma + c\cos\beta}{\sqrt{b^2+c^2+2bc\cos\alpha}} \ldots\ldots (15)$$

$$\text{and } \sec^2(D = 010 \wedge 011) = \frac{b^2+c^2+2bc\cos\alpha}{(b+c\cos\alpha)^2};$$

$$\therefore \tan^2 D = \sec^2 D - 1 = \frac{c^2(1-\cos^2\alpha)}{(b+c\cos\alpha)^2};$$

$$\therefore \tan D = \frac{c\sin\alpha}{b+c\cos\alpha} \ldots\ldots (16)$$

$$\text{Also } \frac{\sin D}{c\sin\alpha} = \frac{\cos D}{b+c\cos\alpha} = \frac{\sin(\alpha - D)}{b\sin\alpha};$$

$$\therefore \frac{b}{c} = \frac{\sin(\alpha - D)}{\sin D} = \frac{\sin D_1}{\sin D} \ldots\ldots (17)$$

This equation, which gives the parametral ratio $\frac{b}{c}$, is given by Grassmann, p. 138; but as he endeavours to connect the ratio with the distances between consecutive particles, his expression differs slightly from

Digitized by Google

the above. It can, by means of the relations (2), be easily transformed into the equations giving the parameters on the corresponding zone-axes. This latter expression is—

$$\frac{c}{b}\frac{\sin\beta}{\sin\gamma} = \frac{\sin D_1}{\sin D};$$

$$\text{Or} \quad \frac{b}{c} = \frac{\sin BL}{\sin CL}\cdot\frac{\sin CA}{\sin AB} \quad \ldots\ldots\ldots(18).$$

By introducing into (7) the values (101) and (110), we get corresponding expressions for the other parametral ratios. They are—

$$\frac{c}{a} = \frac{\sin E_1}{\sin E}, \quad \text{and} \quad \frac{a}{b} = \frac{\sin F_1}{\sin F} \quad \ldots\ldots\ldots(19).$$

Again, if L is $0kl$, we have from the second equation of (7)—

$$\cos BL_1 = -\frac{kb + lc\cos\alpha}{\sqrt{k^2b^2 + l^2c^2 + 2kl\,bc\cos\alpha}},$$

$$\text{whence} \quad \tan BL_1 = \frac{lc\sin\alpha}{kb + lc\cos\alpha} \quad \ldots\ldots\ldots(20).$$

$$\text{and} \quad \frac{\sin BL_1}{\sin(\alpha - BL_1)} = \frac{\sin BL_1}{\sin CL_1} = \frac{lc}{kb} \quad \ldots\ldots\ldots(21)$$

Dividing (21) by (17), we have the anharmonic ratio of the four poles $\{BL_1, LC\}$, which is—

$$\frac{\sin BL_1}{\sin CL_1} \div \frac{\sin BL}{\sin CL} = \frac{l}{k} \quad \ldots\ldots\ldots(22).$$

The deduction of special formulæ for the systems of greater symmetry is easy. We shall at present limit ourselves to the consideration of the rhombohedral system.

Rhombohedral system.

In this system the normals to the fundamental trigonal pyramid or rhombohedron are selected as the axial rays, and the triad axis as the parametral ray (111).

Hence $\alpha = \beta = \gamma$; and $a = b = c = 1$(say).

Equations (5) become—

$$\left.\begin{aligned} OP\cos\lambda &= h + (k+l)\cos\alpha = h(1-\cos\alpha) + \theta\cos\alpha \\ OP\cos\mu &= k(1-\cos\alpha) + \theta\cos\alpha \\ OP\cos\nu &= l(1-\cos\alpha) + \theta\cos\alpha \end{aligned}\right\} \quad \ldots\ldots(23);$$

Where $\theta = h + k + l$.

Digitized by Google

Also, $OP^2=\Sigma h^2+2\cos\alpha\,\Sigma kl=\theta^2\cos\alpha+(1-\cos\alpha)\Sigma h^2$.....(24).

And,

$$\left.\begin{aligned}\cos\lambda&=\frac{h(1-\cos\alpha)+\theta\cos\alpha}{\sqrt{\Sigma h^2+2\cos\alpha\Sigma kl}}\\ \cos\mu&=\frac{k(1-\cos\alpha)+\theta\cos\alpha}{\sqrt{\Sigma h^2+2\cos\alpha\Sigma kl}}\\ \cos\nu&=\frac{l(1-\cos\alpha)+\theta\cos\alpha}{\sqrt{\Sigma h^2+2\cos\alpha\Sigma kl}}\end{aligned}\right\}\ldots\ldots(25).$$

Δ_1 becomes—

$$(1-\cos\alpha)^2(1+2\cos\alpha)-(1-\cos^2\alpha)\,\Sigma\cos^2\lambda+2\cos\alpha(1-\cos\alpha)\Sigma\cos\lambda\cos\mu.$$

Since this is equal to zero, we obtain as the relation between the direction-cosines—

$$(1+\cos\alpha)\Sigma\cos^2\lambda-2\cos\alpha\,\Sigma\cos\lambda\cos\mu=(1-\cos\alpha)(1+2\cos\alpha).....(26).$$

When the ray coincides with the triad axis, $\lambda=\mu=\nu=D=111\wedge100$. Equation (26) then reduces to—

$$3(1-\cos\alpha)\cos^2D=(1-\cos\alpha)(1+2\cos\alpha);$$
$$\therefore\ 3\cos^2D=1+2\cos\alpha.....(27).$$

Hence—
$$2\cos\alpha=\frac{2-\tan^2D}{1+\tan^2D}.....(28).$$

Again,
$$3\sin^2D=2(1-\cos\alpha)=4\sin^2\frac{\alpha}{2}.....(29).$$

This last equation is equivalent to the well-known formula—

$$\sin r'r/2=\sin 60^\circ\sin D;$$

Where r and r' are two poles of the fundamental rhombohedron.

The expression (14) for the cosine of the angle between the rays (hkl) and $(h_1k_1l_1)$ becomes—

$$\cos\phi=\frac{\Sigma hh_1+\cos\alpha\Sigma(kl_1+k_1l)}{\sqrt{\Sigma h^2+2\cos\alpha\,\Sigma kl}\quad\sqrt{\Sigma h_1^2+2\cos\alpha\,\Sigma k_1l_1}}.....(30).$$

If $\cos\alpha$ is replaced by its equivalent given in (28), we obtain the following expressions for the cosine:—

$$\cos\phi=\frac{2\{\Sigma hh_1+\Sigma(kl_1+k_1l)\}+\tan^2D\{2\Sigma hh_1-\Sigma(kl_1+k_1l)\}}{\sqrt{2(\Sigma h^2+2\Sigma kl)+2\tan^2D(\Sigma h^2-\Sigma kl)}\quad\sqrt{2(\Sigma h_1^2+2\Sigma k_1l_1)+2\tan^2D(\Sigma h_1^2-\Sigma k_1l_1)}}$$

$$=\frac{2\theta\theta_1+\tan^2D\Sigma(k-l)(k_1-l_1)}{\sqrt{2\theta^2+\tan^2D\Sigma(k-l)^2}\quad\sqrt{2\theta_1^2+\tan^2D\Sigma(k_1-l_1)^2}}.....(31);$$

where $\theta_1=h_1+k_1+l_1$.

Digitized by Google

By means of the equations above given, and the relations of the spherical triangles formed by P with the axial poles and with the poles C, N, m, m', m'', a', &c., marked in Fig. 2, we can easily establish the relations in general use for the solution of problems respecting rhombohedral crystals.

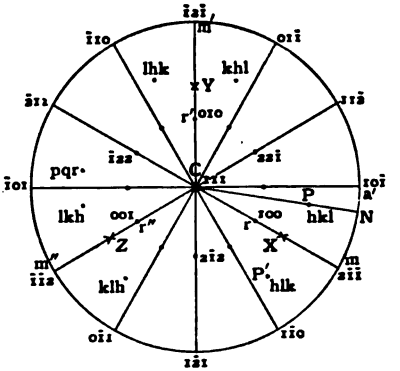


Fig. 2.

Or employing the general equations (30) and (31), and C being (111), we have—

$$\cos CP = \frac{\theta\sqrt{(1+\overline{2}\,\overline{\cos\alpha})}}{\sqrt{3\{\Sigma h^2+2\cos\alpha\Sigma kl\}}}$$

$$= \frac{\theta\sqrt{\overline{2}}}{\sqrt{2\theta^2+\tan^2 D\Sigma(k-l)^2}} \ldots\ldots\ldots(32).$$

By transforming the first equivalent, we have—

$$\tan CP = \frac{\sqrt{(1-\cos\alpha)\Sigma(k-l)^2}}{\theta\sqrt{(1+2\cos\alpha)}} \ldots\ldots\ldots(33).$$

By transforming the second equivalent, we obtain—

$$\tan CP = \frac{\sqrt{\Sigma(k-l)^2}}{\theta\sqrt{\overline{2}}}\tan D\ldots\ldots\ldots(34);$$

and this can be shown to be the result of replacing $\cos\alpha$ in (33) by its equivalent in terms of $\tan D$.

Again, taking 2ξ, 2η to be the angles, respectively, over the obtuse and acute polar edges of a scalenohedron $\{hkl\}$, and 2ζ to be that over each of its median edges, we have—

$$\cos 2\xi = \cos hkl\wedge hlk = \frac{h^2+2kl+\cos\alpha\{\theta^2-(h^2+2kl)\}}{\Sigma h^2+2\cos\alpha\Sigma kl}$$

$$= \frac{2\theta^2+\tan^2 D\{3(h^2+2kl)-\theta^2\}}{2\theta^2+\tan^2 D\Sigma(k-l)^2} \ldots\ldots\ldots(35).$$

Digitized by Google

$$\text{Hence } 2\sin^2\xi = \frac{2(k-l)^2\sin^2\frac{\alpha}{2}}{\Sigma h^2+2\cos\alpha\,\Sigma kl} = \frac{3(k-l)^2\tan^2 D}{2\theta^2+\tan^2 D\,\Sigma(k-l)^2} \quad \ldots\ldots(36).$$

Similarly,

$$\cos 2\eta = \cos(hkl\wedge khl) = \frac{l^2+2hk+\cos\alpha\{\theta^2-(l^2+2hk)\}}{\Sigma h^2+2\cos\alpha\,\Sigma kl}$$

$$= \frac{2\theta^2+\tan^2 D\{3(l^2+2hk)-\theta^2\}}{2\theta^2+\tan^2 D\,\Sigma(k-l)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(37).$$

$$\therefore\ 2\sin^2\eta = \frac{2(h-k)^2\sin^2\frac{\alpha}{2}}{\Sigma h^2+2\cos\alpha\,\Sigma kl} = \frac{3(h-k)^2\tan^2 D}{2\theta^2+\tan^2 D\,\Sigma(k-l)^2} \quad \ldots\ldots(38).$$

And—

$$\cos 2\zeta = \cos hkl\wedge\bar{l}\bar{k}\bar{h} = \frac{-(k^2+2hl)-\cos\alpha\{\theta^2-(k^2+2hl)\}}{\Sigma h^2+2\cos\alpha\,\Sigma kl}$$

$$= \frac{-2\theta^2-\tan^2 D\{3(k^2+2hl)-\theta^2\}}{2\theta^2+\tan^2 D\,\Sigma(k-l)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(39).$$

Hence

$$2\cos^2\zeta = \frac{2(h-l)^2\sin^2\frac{\alpha}{2}}{\Sigma h^2+2\cos\alpha\,\Sigma kl} = \frac{3(h-l)^2\tan^2 D}{2\theta^2+\tan^2 D\,\Sigma(k-l)} \quad \ldots\ldots\ldots(40).$$

Now each of the angles ξ, η, ζ is less than 90°, for the angles over the scalenohedral edges are each less than 180°. Therefore taking, as we are at liberty to do, h, k and l to be in descending order of magnitude, and their sum to be greater than unity, the positive values must be taken when the square roots of equations (36), (38) and (40) are extracted. We have, therefore,—

$$\left.\begin{aligned}
\sin\xi &= \frac{(k-l)\sin\frac{\alpha}{2}}{\sqrt{\Sigma h^2+2\cos\alpha\Sigma kl}} = \frac{(k-l)\sqrt{3}\tan D}{\sqrt{4\theta^2+2\tan^2 D\Sigma(k-l)^2}};\\
\sin\eta &= \frac{(h-k)\sin\frac{\alpha}{2}}{\sqrt{\Sigma h^2+2\cos\alpha\Sigma kl}} = \frac{(h-k)\sqrt{3}\tan D}{\sqrt{4\theta^2+2\tan^2 D\Sigma(k-l)^2}};\\
\cos\zeta &= \frac{(h-l)\sin\frac{\alpha}{2}}{\sqrt{\Sigma h^2+2\cos\alpha\Sigma kl}} = \frac{(h-l)\sqrt{3}\tan D}{\sqrt{4\theta^2+2\tan^2 D\Sigma(k-l)^2}}
\end{aligned}\right\} \quad \ldots\ldots\ldots(41).$$

Digitized by Google

Hence,

$$\frac{\sin\xi}{k-l}=\frac{\sin\eta}{h-k}=\frac{\cos\zeta}{h-l}=\frac{\sin\frac{a}{2}}{\sqrt{\Sigma h^2+2\cos a\Sigma kl}}$$

$$=\text{(by transformation from (32))}\ \frac{\sqrt{3}\sin CP}{\sqrt{2\Sigma(k-l)^2}}=\frac{\sqrt{3}\tan D}{\sqrt{4\theta^2+2\tan^2 D\,\Sigma(k-l)^2}}$$

$$=\text{(from (32))}\ \frac{\sqrt{3}\tan D\cos CP}{2\theta}\ldots\ldots(42);$$

$$\text{and } \sin\xi+\sin\eta=\cos\zeta\ldots\ldots(43).$$

Digitized by Google

On the determination of the positions of points and planes after rotation through a definite angle about a known axis.

By R. W. H. T. Hudson, B.A,
Communicated by Prof. W. J. Lewis, M.A.

[Read April 3rd, 1900.]

I.

Rectangular axes.

TAKE three axes of reference OX, OY, OZ mutually at right angles. A convention must be made as to the positive direction of rotation about any line, and that usually adopted is as follows. A positive rotation about OX rotates OY towards OZ, one about OY rotates OZ towards OX, and one about OZ rotates OX towards OY. To find the positive direction of rotation for any line ON we must suppose ON moved to coincide with one of the axes, say OZ, and then apply the preceding rule.

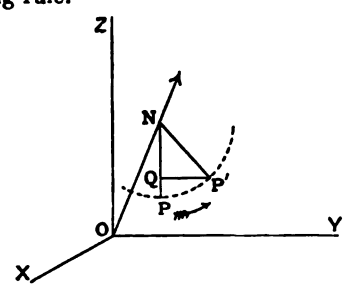


Fig. 1.

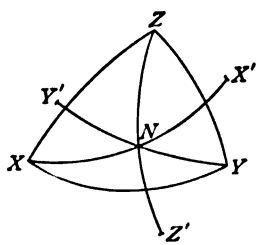


Fig. 2.

Taking the axes as indicated in the figure, in which OX is supposed drawn towards the observer, a positive rotation about any line ON together with a translation along ON produces right handed screwing. If the axes OX and OY were interchanged, the screwing would be left-handed.

The figure represents the displacement of a point P to the position P' by rotation through an angle ϕ about ON in the positive direction. The problem is to determine the co-ordinates $(x'y'z')$ of P' in terms of those of $P(xyz)$, ϕ and the given direction ON.

Digitized by Google

Let $\angle NOX = \lambda$, $\angle NOY = \mu$, $\angle NOZ = \nu$.

PN, $P'N$ are perpendicular to ON and $\angle PNP' = \phi$.

$P'Q$ is perpendicular to NP.

To find ON we notice that it is the projection of OP on ON. Hence

$$ON = OP \cos PON = OP\left\{\frac{x}{OP}\cos\lambda + \frac{y}{OP}\cos\mu + \frac{z}{OP}\cos\nu\right\}$$
$$= x\cos\lambda + y\cos\mu + z\cos\nu \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

It is convenient to use the co-ordinates of N which are $\xi\eta\zeta$ where

$$\xi = ON\cos\lambda = (x\cos\lambda + y\cos\mu + z\cos\nu)\cos\lambda$$
$$\eta = ON\cos\mu = (x\cos\lambda + y\cos\mu + z\cos\nu)\cos\mu$$
$$\zeta = ON\cos\nu = (x\cos\lambda + y\cos\mu + z\cos\nu)\cos\nu$$

The direction of QP' is required.

The direction-cosines of ON are $\cos\lambda$, $\cos\mu$, $\cos\nu$.

,, NP ,, $\frac{x-\xi}{NP}$, $\frac{y-\eta}{NP}$, $\frac{z-\zeta}{NP}$.

or say p , q , r .

Hence those of QP', which is perpendicular to both, are

$$\pm(r\cos\mu - q\cos\nu),\ \pm(p\cos\nu - r\cos\lambda),\ \pm(q\cos\lambda - p\cos\mu).$$

The ambiguous sign is determined by the fact that, if ON be moved to coincide with OZ and NP to the direction OX, QP' will then be in the direction OY. That is, when $\cos\lambda = 0 = \cos\mu$, $\cos\nu = 1$, $p = 1$, $q = 0 = r$, we must have

$$\pm(p\cos\nu - r\cos\lambda) = 1.$$

Hence the upper sign must be taken.

We are now in a position to write down the co-ordinates of P', because we know the lengths and directions of ON, NQ, QP'.

Thus $x' = ON\cos\lambda + NQ.p + QP'(r\cos\mu - q\cos\nu)$
$= \xi + NP'\cos\phi.\frac{x-\xi}{NP} + NP'\sin\phi\,(r\cos\mu - q\cos\nu)$
$= \xi + \cos\phi\,(x-\xi) + \sin\phi\,(z\cos\mu - y\cos\nu)$

Or $x' - x = (1-\cos\phi)(\xi - x) + \sin\phi\,(z\cos\mu - y\cos\nu)$
Similarly, $y' - y = (1-\cos\phi)(\eta - y) + \sin\phi\,(x\cos\nu - z\cos\lambda)$
and $z' - z = (1-\cos\phi)(\zeta - z) + \sin\phi\,(y\cos\lambda - x\cos\mu)$ ..... (2);

wherein ξ, η, ζ have the values found above.

Digitized by Google

The relations (2), which give the new position of any point, are established in Minchin's *Statics*, II, p. 103, 1889; and his method of proof is that followed above.

If $x\ y\ z$ are required in terms of $x'y'z'$, it is necessary only to interchange x and x', &c. in the above formulæ and to change the sign of ϕ.

Suppose that it is required to find the new position of a plane

$$hx/a+ky/b+lz/c=1.$$

Now the point $h/a,\ k/b,\ l/c$ is the pole P of this plane with respect to the sphere

$$x^2+y^2+z^2=1;$$

and the relation of pole and polar is unchanged by any rotation about 0. Hence the new position of the plane is

$$h'x/a+k'y/b+l'x/c=1;$$

where $h'/a,\ k'/b,\ l'/c$ are the co-ordinates of the new position P' of the original pole P. They are therefore obtained from (2), and are

$$\left.\begin{aligned}
\frac{h'}{a} &= \frac{h}{a}\cos\phi+ON\cos\lambda\,(1-\cos\phi)+\sin\phi\left(\frac{l}{c}\cos\mu-\frac{k}{b}\cos\nu\right)\\
\frac{k'}{b} &= \frac{k}{b}\cos\phi+ON\cos\mu\,(1-\cos\phi)+\sin\phi\left(\frac{h}{a}\cos\nu-\frac{l}{c}\cos\lambda\right)\\
\frac{l'}{c} &= \frac{l}{c}\cos\phi+ON\cos\nu\,(1-\cos\phi)+\sin\phi\left(\frac{k}{b}\cos\lambda-\frac{h}{a}\cos\mu\right)
\end{aligned}\right\}\quad\ldots\ldots(3),$$

where $ON=\dfrac{h}{a}\cos\lambda+\dfrac{k}{b}\cos\mu+\dfrac{l}{c}\cos\nu.$

II. *Oblique axes.*

Choose rectangular axes as in case I, and let the oblique axes, referred to them, have direction cosines $(l_1m_1n_1)$, $(l_2m_2n_2)$, $(l_3m_3n_3)$.

Let OP make angles $\theta_1\ \theta_2\ \theta_3$ with the oblique axes.

$$\text{Then } \cos\theta_i=(l_ix+m_iy+n_iz)\div OP,\ (i=1,2,3).$$

It is required to find the angles $\theta_1'\ \theta_2'\ \theta_3'$ made by OP' with the oblique axes.

We have $\cos\theta_i'=(l_ix'+m_iy'+n_iz')\div OP',\ (i=1,\ 2,\ 3).$

Hence, multiplying the formulæ (2) respectively by $\dfrac{l}{OP}$, $\dfrac{m}{OP}$, $\dfrac{n}{OP}$ (dropping the suffix) and adding, we obtain

$$\cos\theta'=\cos\phi\cos\theta+(1-\cos\phi)\frac{l\xi+m\eta+n\zeta}{OP}+\sin\phi\begin{vmatrix}\dfrac{l}{OP} & \dfrac{m}{OP} & \dfrac{n}{OP}\\ \cos\lambda & \cos\mu & \cos\nu\\ \dfrac{x}{OP} & \dfrac{y}{OP} & \dfrac{z}{OP}\end{vmatrix}$$

Digitized by Google

Now, if the axis of rotation ON makes angles $\omega_1\ \omega_2\ \omega_3$ with the oblique axes, then

$$\cos\omega_i = l_i \frac{\xi}{ON} + m_i \frac{\eta}{ON} + n_i \frac{\zeta}{ON}, (i=1, 2, 3).$$

$\therefore \cos\theta_i' = \cos\phi\cos\theta_i + (1-\cos\phi).\cos PON.\cos\omega_i + \sin\phi\,\Delta_i$.....(4).

where

$$\Delta_i^2 =$$

$$\begin{vmatrix} l_i^2+m_i^2+n_i^2, & l_i\cos\lambda+m_i\cos\mu+n_i\cos\nu, & l_i\frac{x}{OP}+m_i\frac{y}{OP}+n_i\frac{z}{OP} \\ l_i\cos\lambda+m_i\cos\mu+n_i\cos\nu, & \cos^2\lambda+\cos^2\mu+\cos^2\nu, & \cos\lambda\frac{x}{OP}+\cos\mu\frac{y}{OP}+\cos\nu\frac{z}{OP} \\ l_i\frac{x}{OP}+m_i\frac{y}{OP}+n_i\frac{z}{OP}, & \cos\lambda\frac{x}{OP}+\cos\mu\frac{y}{OP}+\cos\nu\frac{z}{OP}, & \frac{x^2+y^2+z^2}{OP^2} \end{vmatrix}$$

$$= \begin{vmatrix} 1 & \cos\omega_i & \cos\theta_i \\ \cos\omega_i & 1 & \cos PON \\ \cos\theta_i & \cos PON & 1 \end{vmatrix} \quad \text{.....(5).}$$

It remains only to calculate $\cos PON$ in terms of $\omega_1\ \omega_2\ \omega_3$, $\theta_1\ \theta_2\ \theta_3$, and the angles α, β, γ between the oblique axes.

Let e, f, g be the direction ratios of OP.

Construct a parallelepiped, having OP as diagonal, and edges parallel to the oblique axes, and project on ON, we then obtain

$$\cos PON = e\cos\omega_1 + f\cos\omega_2 + g\cos\omega_3.$$

Again, projecting on the oblique axes, we get—

$$\cos\theta_1 = e + f\cos\gamma + g\cos\beta$$
$$\cos\theta_2 = e\cos\gamma + f + g\cos\alpha$$
$$\cos\theta_3 = e\cos\beta + f\cos\alpha + g$$

Eliminate e, f, g.

$$\therefore \begin{vmatrix} \cos PON & \cos\omega_1 & \cos\omega_2 & \cos\omega_3 \\ \cos\theta_1 & 1 & \cos\gamma & \cos\beta \\ \cos\theta_2 & \cos\gamma & 1 & \cos\alpha \\ \cos\theta_3 & \cos\beta & \cos\alpha & 1 \end{vmatrix} = 0$$

Or $\cos PON \begin{vmatrix} 1 & \cos\gamma & \cos\beta \\ \cos\gamma & 1 & \cos\alpha \\ \cos\beta & \cos\alpha & 1 \end{vmatrix} + \begin{vmatrix} 1 & \cos\gamma & \cos\beta & \cos\theta_1 \\ \cos\gamma & 1 & \cos\alpha & \cos\theta_2 \\ \cos\beta & \cos\alpha & 1 & \cos\theta_3 \\ \cos\omega_1 & \cos\omega_2 & \cos\omega_3 & 0 \end{vmatrix} = 0$ .....(6)

Thus $\cos I\,ON$ is found, and thence Δ_1, Δ_2, Δ_3, and the result may be stated as follows:

Digitized by Google

If the line OP, making angles $\theta_1\ \theta_2\ \theta_3$ with the axes, is turned through an angle ϕ about ON, making angles $\omega_1\ \omega_2\ \omega_3$ with the axes, into the position OP' having the direction-angles $\theta_1'\ \theta_2'\ \theta_3'$, then

$$\cos\theta_i' = \cos\phi\cos\theta_i + (1-\cos\phi)\cos PON\cos\omega_i + \sin\phi\,\Delta_i, (i=1,2,3).$$

To find the new position of any plane we notice that the direction cosines of the normal to the plane $h\frac{x}{a}+k\frac{y}{b}+l\frac{z}{c}=1$ are $\rho\frac{h}{a}$, $\rho\frac{k}{b}$, $\rho\frac{l}{c}$, where ρ is the perpendicular from O on the plane, and is unaltered by the rotation.

Thus the formulæ required are:

$$\left.\begin{aligned}\frac{h'}{a} &= \frac{h}{a}\cos\phi+(1-\cos\phi)\frac{\cos PON}{\rho}\cos\omega_1+\sin\phi\,D_1\\ \frac{k'}{b} &= \frac{k}{b}\cos\phi+(1-\cos\phi)\frac{\cos PON}{\rho}\cos\omega_2+\sin\phi\,D_2\\ \frac{l'}{c} &= \frac{l}{c}\cos\phi+(1-\cos\phi)\frac{\cos PON}{\rho}\cos\omega_3+\sin\phi\,D_3\end{aligned}\right\}\ldots\ldots(7)$$

where

$$-\frac{\cos PON}{\rho} = \begin{vmatrix} 1 & \cos\gamma & \cos\beta & h/a\\ \cos\gamma & 1 & \cos\alpha & k/b\\ \cos\beta & \cos\alpha & 1 & l/c\\ \cos\omega_1 & \cos\omega_2 & \cos\omega_3 & 0\end{vmatrix} \div \begin{vmatrix} 1 & \cos\gamma & \cos\beta\\ \cos\gamma & 1 & \cos\alpha\\ \cos\beta & \cos\alpha & 1\end{vmatrix};\ldots\ldots(8)$$

$$D_1^2 = \begin{vmatrix} 1 & \cos\omega_1 & h/a\\ \cos\omega_1 & 1 & \rho^{-1}\cos PON\\ h/a & \rho^{-1}\cos PON & \rho^{-2}\end{vmatrix};\ \&c.;\ \ldots\ldots(9)$$

and ρ is given by

$$\begin{vmatrix} 1 & \cos\gamma & \cos\beta & h/a\\ \cos\gamma & 1 & \cos\alpha & k/b\\ \cos\beta & \cos\alpha & 1 & l/c\\ h/a & k/b & l/c & \rho^{-2}\end{vmatrix} = 0\ldots\ldots\ldots\ldots(10)$$

When the angle of rotation is 180° the formulæ of transformation can be obtained directly as follows:

Let as before the plane $hx/a+ky/b+lz/c=1$ become

$$h'x/a+k'y/b+l'z/c=1.$$

The relative motion of the plane and axes is the same as if the plane were fixed and the axes were turned through 180° about ON. Let the

Digitized by Google

axes meet a sphere with radius ON in X, Y, Z, Fig. 2, p. 343; and let their positions after a semi-revolution about ON be given by X', Y', Z'.

Then $$X'N=NX;\ Y'N=NY;\ Z'N=NZ.$$

And

$$\left.\begin{array}{l}\text{Cos } X'X=\cos 2\,XN=2\cos^2 XN-1=2\cos^2\omega_1-1.\\ \text{Cos } X'Y+\cos XY=2\cos XN\cos YN;\ \therefore\cos X'Y=2\cos\omega_1\cos\omega_2-\cos\gamma.\\ \text{Cos } X'Z+\cos XZ=2\cos XN\cos ZN;\ \therefore\cos X'Z=2\cos\omega_1\cos\omega_3-\cos\beta.\end{array}\right\}\ldots(11)$$

But $x\ y\ z$ being the point at distance r on OX' at which the plane is met, then

$$\left.\begin{array}{l}r\cos XX'=x+y\cos\gamma+z\cos\beta,\\ r\cos YX'=x\cos\gamma+y+z\cos\alpha,\\ r\cos ZX'=x\cos\beta+y\cos\alpha+z.\\ 1=hx/a+ky/b+lz/c\end{array}\right\}\ldots\ldots(12)$$

Eliminating x, y and z, and replacing cos XX', &c. by their values given in (11), and r by its equivalent $a\div h'$, we have—

$$\begin{vmatrix}2\cos^2\omega_1-1 & 1 & \cos\gamma & \cos\beta\\ 2\cos\omega_1\cos\omega_2-\cos\gamma & \cos\gamma & 1 & \cos\alpha\\ 2\cos\omega_1\cos\omega_3-\cos\beta & \cos\beta & \cos\alpha & 1\\ \dfrac{(h'+h)-h}{a}, & \dfrac{h}{a} & \dfrac{k}{b} & \dfrac{l}{c}\end{vmatrix}=0.$$

This reduces to

$$\begin{vmatrix}\cos\omega_1 & 1 & \cos\gamma & \cos\beta\\ \cos\omega_2 & \cos\gamma & 1 & \cos\alpha\\ \cos\omega_3 & \cos\beta & \cos\alpha & 1\\ \dfrac{h_1+h}{2a\cos\omega_1} & \dfrac{h}{a} & \dfrac{k}{b} & \dfrac{l}{c}\end{vmatrix}=0\ldots\ldots(13\ ;$$

which may be expressed by

$$(h_1+h)D-2a\cos\omega_1\Delta=0.$$

The formulæ of transformation are therefore

$$\frac{h'+h}{a\cos\omega_1}=\frac{k'+k}{b\cos\omega_2}=\frac{l'+l}{c\cos\omega_3}=\frac{2\Delta}{D}\ldots\ldots(14)\ ;$$

where

$$\Delta=\begin{vmatrix}\cos\omega_1 & 1 & \cos\gamma & \cos\beta\\ \cos\omega_2 & \cos\gamma & 1 & \cos\alpha\\ \cos\omega_3 & \cos\beta & \cos\alpha & 1\\ 0 & \dfrac{h}{a} & \dfrac{k}{b} & \dfrac{l}{c}\end{vmatrix},\ \text{and}\ D=\begin{vmatrix}1 & \cos\gamma & \cos\beta\\ \cos\gamma & 1 & \cos\alpha\\ \cos\beta & \cos\alpha & 1\end{vmatrix}.$$

Digitized by Google

Communications from the Oxford Mineralogical Laboratory.

1. *On a Rhombic Pyroxene from South Africa.*

2. *On a method of illustrating the variation of thermal conductivity of crystals in different directions.*

3. *A twin crystal of Sapphire.*

4. *On Monazite and associated minerals from Tintagel, Cornwall.*

By H. L. Bowman, M.A., Demonstrator in Mineralogy.

1. *On a Rhombic Pyroxene from South Africa.*

[Read June 20th, 1899.]

THE stones to which this paper refers were sent to Prof. Miers for determination by Mr. Francis Powell, and were stated to come "from the diamond washings." They are of a fine green colour, and quite transparent, and possess a highly perfect cleavage parallel to the faces of a prism having an angle of about 88°. This serves to distinguish the material from olivine, which it otherwise much resembles, and —coupled with the uniformly straight extinction through cleavage flakes, the specific gravity (3·199) and hardness (6—7)—suffices to identify the mineral as one of the rhombic pyroxenes.

Since unaltered rhombic pyroxenes, such as the present, are rare, and but few of the known occurrences have ever been completely examined, it seemed desirable to submit the stones to a thorough examination.

The mineral occurs in small irregular fragments up to 6 or 8 mm. in diameter, devoid of crystal faces, but partly bounded in some cases by cleavage planes, the surface being perfectly fresh. In addition to the very good prismatic cleavage of 88°0′ (mean of 15 measurements), there are two other less perfect cleavages, parallel to $a(100)$ and $b(010)$ respectively. These are visible on some fragments as numerous minute parallel surfaces, which give a good single image of the goniometer signal. They are also brought out in grinding sections perpendicular to the prism. The cleavages are not always easily obtained, and the crystals often show a conchoidal fracture. The prismatic cleavage-angle corresponds to an axial ratio—$a : b = 0{\cdot}9657 : 1$.

Digitized by Google

The surface of the fragments often has a characteristic drusy appearance due to the cleavage, and one specimen shows a platy structure, as if due to a twin-parting parallel to $b(010)$. This, together with occasional absence of extinction and a fracture recalling the "ripple fracture" of quartz, probably indicates the existence of twin-lamellation. The stones have a fine green colour, sometimes of a rather light shade and inclining to olive, and are quite clear and transparent, closely resembling in appearance some varieties of olivine. The sp. gr. is 3·199, and the hardness between 6 and 7. The lustre is vitreous, and the streak nearly colourless. Several of the cleavage prisms show a fine straight line running transversely across them, the cleavage surfaces on either side of the line not being quite in the same plane. I have measured 8 crystals, and find that the cleavages on the two parts are inclined to one another at a constant angle of about 2°10′, the numbers varying between 2°1′ and 2°16′, and the mean of 6 measurements being 2°9½′. The disposition of the salient and re-entrant angles shows that the (100) faces of both individuals would lie in the same plane, and that the (010) faces would be inclined to one another at an angle of 3°6′. If the combination is to be considered a twin, the indices of the twin-plane would be near to (0.1.21).

In polarised light cleavage flakes show straight extinction, and in convergent sodium light a cleavage prism affords traces of a wide angle — bisectrix at the edge of the field, the plane of the optic axes lying parallel to the trace of the cleavage, and the bisectrix emerging in the equatorial plane. (This bisectrix does not, however, emerge through the horizontal plane, but through the second cleavage at the side of the prism.)

The plane of the optic axes is parallel to $b(010)$, *i.e.* to the shorter diagonal of the cleavage prism, the + acute bisectrix being parallel to the vertical axis $\dot{c}$. Thus, the optical scheme is $\alpha\ \beta\ \gamma = a\ b\ c$.

The birefringence is rather weak.

For the measurement of the optic axial angle two fragments were ground down to plates parallel to $c(001)$ and $a(100)$.[1] The plates were immersed in olive oil, of refractive index 1·4707, and gave the following values for 2H:—

$$2H_a = 88°34' \qquad 2H_o = 135°24' \text{ (Na light)};$$
$$\text{whence } 2V = 74°\ 5' \quad \text{and } \beta = 1{\cdot}705.$$

[1] The perfect prismatic cleavage rendered this a process of some difficulty. I found fine carborundum, used with water on an iron or pewter lap, to be the most convenient grinding material, as flour emery is exceedingly slow in action, and coarser emery is very apt to break the specimen along the cleavages.

Digitized by Google

The dispersion about the acute bisectrix is $\rho > v$.

In order to determine the refractive indices I employed a prism, for the preparation of which Mr. Fletcher kindly allowed me to use the Tutton cutting and grinding instrument in the British Museum. The material at my command only sufficed for the preparation of one prism, and this was ground so that its angle is approximately bisected by the plane (100), and its edge is parallel to the vertical axis. The bisecting plane deviates about 1° from the plane (100), but this error will not materially affect the value of the resulting indices. The values of β and γ obtained with this prism are:—

$$\left.\begin{array}{rcl} \beta & = & 1{\cdot}669 \\ \gamma & = & 1{\cdot}675 \end{array}\right\} \text{ (Na light)}^1.$$

The pleochroism is rather weak:—

$\breve{a}$ pale yellow $\bar{b}$ pale green $\dot{c}$ pale yellowish-green

An approximate analysis of some of the material yielded me the following numbers:—

$SiO_2 = 56{\cdot}0$, $FeO = 5{\cdot}0$, $MnO = 0{\cdot}5$, $Al_2O_3 = 2{\cdot}5$, $Cr_2O_3 = 0{\cdot}6$, $MgO = 36{\cdot}5 \ldots . = 101{\cdot}1$

I learn from Mr. Powell that he has received the stones from different sources, the association being with "a darker blackish green stone and fine red garnet." Some are said to be from Griqualand West, where they are found in the diamond washings.

In the Museum of Practical Geology I have found among the exhibits from the Diamond Fields two specimens of washings, from Kimberley Mine and from Du Toit's Pan respectively, which contain green fragments closely resembling the present material in colour and drusy surface-appearance, and it seems not improbable that they may be identical with it, as in specific gravity they fall within the same limits. They are associated with red garnet (which forms the chief constituent of the washings), quartz, and a little iron pyrites.

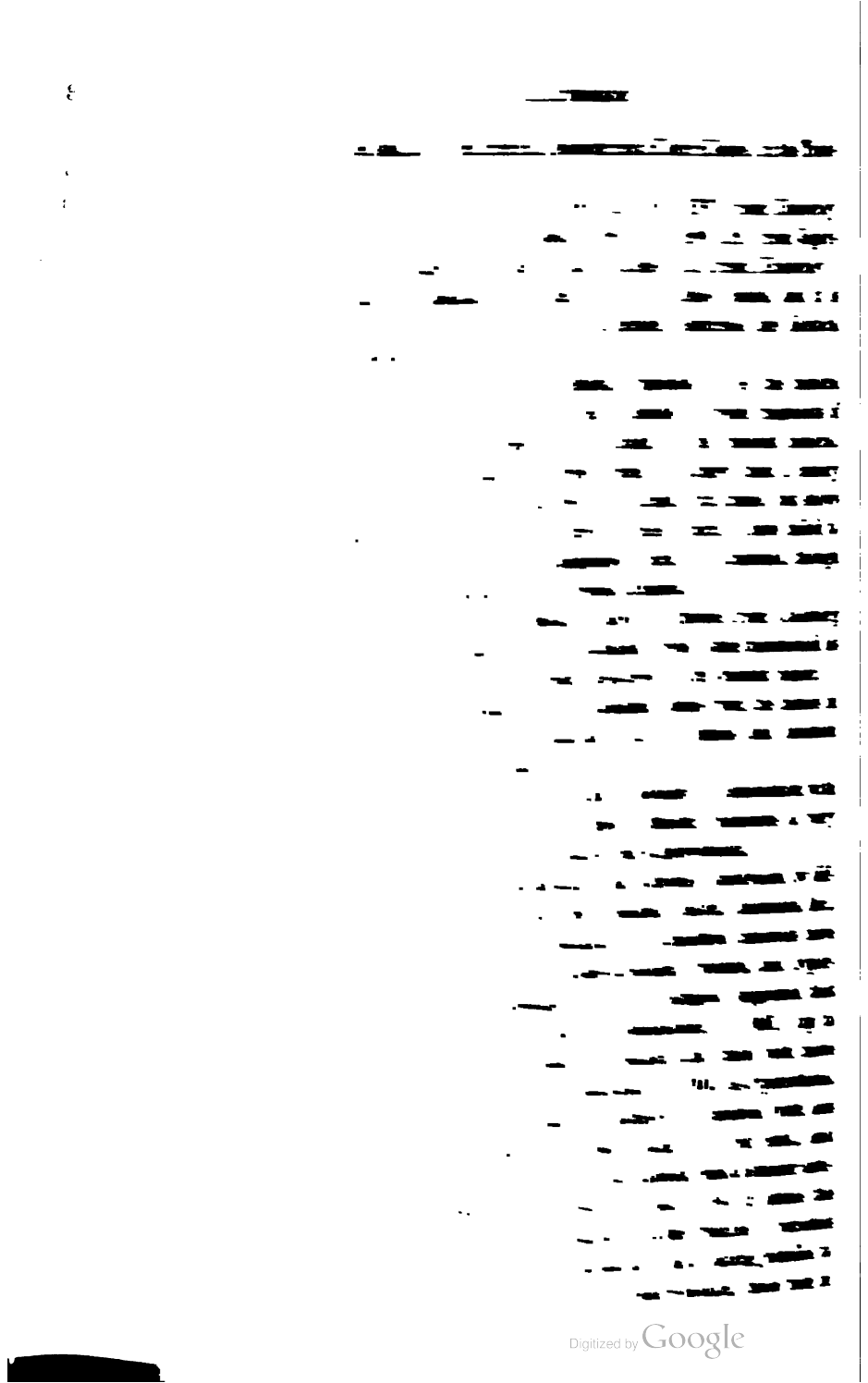
Green transparent rhombic pyroxenes have been already described from South Africa, namely:—

By Maskelyne and Flight [*Q. J. G. S.* XXX, 406, 1874] from the "blue ground" at Du Toit's Pan, Bultfontein, and Colesberg Kopje—all in the neighbourhood of Kimberley.

---

[1] The difference between the values of β as calculated from the axial angle and as measured with the prism, may perhaps be due to a variation in the optical characters of the three specimens used, corresponding to a slight observed difference in the specific gravity. The prism value is probably the most reliable.

Digitized by Google



Digitized by Google

FeO under hypersthene. The obvious boundary is at about 10 per cent. FeO, corresponding to the change in optical sign.

According to this arrangement the present mineral, with 5·0 per cent. FeO, will be classed as enstatite.

---

2. *On a Method of illustrating the Variation of Thermal Conductivity of Crystals in different directions.*

[Read Feb. 1, 1898.]

WHILE endeavouring some time ago to produce, for demonstration purposes, a satisfactory specimen to show the "Curve of Conductivity for Heat," I hit upon a method which may be worthy of mention, as it is exceedingly simple, and gives results which are at once clearly visible and permanent.

I have as yet only tried the method on gypsum and copper sulphate, but it might, no doubt, be applied to other substances containing water of crystallisation.

The gypsum crystals on which the experiments were made were obtained from Shotover Hill, near Oxford.

A stout brass wire ($\frac{3}{16}$ inch. dia.) is filed at one end to a conical point. It is then supported in a vertical position with its point resting on the face of the crystal, and is heated by means of a Bunsen burner directed horizontally at a point 1 or 2 ins. above the end. The water of crystallisation is driven off by the heat, and an opaque white spot formed round the point. This spot has an elliptic outline, which approximates to the curve of conductivity.

If figures be produced on faces belonging to different forms, they can be seen to vary, in the directions and ratios of their axes, in accordance with the symmetry of the crystal (Fig. 1). Figures may readily be obtained with a major axis of 5-6 mm. or more, but beyond this size the outline is rather apt to become irregular, the opacity extending outwards in streaks which, on the cleavage face, run nearly parallel with the edge b/l, [010 : 111].

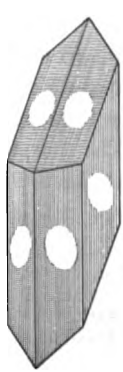


Fig. 1.

No advantage appears to be gained by screening the crystal from the direct radiation from the source of heat.

Under the microscope the white patch is seen, near the margin, to consist of dots, which (with a $\frac{1}{4}$ in. objective)

Digitized by Google

show a form like that of the "Verwitterungsflecken" figured by Sohncke (*Zeits. Kryst.* XXX, 1, 1899).[1]

The outline of the figures is usually somewhat indefinite, as the dots, which overlap in the centre, are at the edge more sparsely distributed. The shading-off is, however, fairly regular, and allows of the determination of the ratio $\left(\frac{a}{b}\right)$ of the axes of the ellipse, with some approach to accuracy. I have measured some of the smaller figures on a cleavage face under the microscope, with the following results:—

Face.	Outline.	a	b	$\frac{a}{b}$	mean $\frac{a}{b}$
(010) Cleavage	very sharp	10·0	9·2	1·09	1·129
	sharp	13·5	12·0	1·116	
	,,	13·0	11·6	1·12	
	fair	14·0	12·0	1·166	
	hazy	14·0	12·5	1·12	
	,,	13·0	11·5	1·13	
	very sharp	12·5	11·2	1·12	
	fair	15·6	13·2	1·18	
	,,	14·0	12·5	1·12	

Using the same method of heating, combined with Senarmont's wax coating, I obtained from 8 ellipses a mean ratio, $\frac{a}{b}=1{\cdot}151$, the limits being 1·077 and 1·25. A nearer approximation between the two methods is hardly to be expected, on account of the disorganisation of the structure of the crystal by the high temperature. The value obtained by Senarmont on gypsum from Montmartre was $\frac{a}{b}=1{\cdot}23$. The opacity extends downwards from the surface into the crystal, inside which it has an ellipsoidal shape, which, in the case of faces inclined to the plane of symmetry, is seen to be oblique to the surface.

The sharpness of the figures is improved if the irregularities of the face have been first removed by grinding with water on a sheet of ground glass.

---

[1] By exposing crystals of Gypsum from Bex to a temperature of about 100° in an air bath, Pape (*Pogg. Ann.* cxxxv. 4, 1868) obtained elliptical figures pointing to the existence of an ellipsoid ("Verwitterungsellipsoid"), similar to those calculated by him in the case of copper sulphate, &c. Later observers, *e.g.* Sohncke (*l.c.*), have induced by the same method polygonal and not elliptical spots.

Digitized by Google

The figures on the face *b* are usually traversed by 3 radiating cracks, somewhat resembling the percussion figure of mica. The principal of these runs parallel to the edge *b*/*l*, [010 : 111] ; another parallel to the edge *b*/*m*, [010 : 110]; and the third makes an angle of about 16° with the direction of fibrous fracture, lying between this and the vertical axis.

Some cleavage plates of gypsum from Montmartre, which I have tried, do not give quite such regular figures as the Shotover material, but the radiating cracks and the Sohncke figures are particularly clear.

The production of the larger figures may occupy an hour, but good small figures may be made in a few minutes.

Senarmont's first paper (*Ann. Chim. Phys.* [3], XXI, 466, 1847) on the conductivity of crystals for heat, mentions that he obtained similar dehydration figures in gypsum when the wire passing through the perforated crystal was strongly heated. It would seem, however, either that the observation has escaped notice (with the exception of an incidental mention by Jannettaz (*Ann. Chim. Phys.* [4], XXIX, 23, 1873), or that the simplicity of the method, especially in the form described above, and its adaptation to demonstration purposes, have not been recognised.

According to the few experiments I have made, copper sulphate does not readily yield such good figures as gypsum, but the deviation from a circular form is, nevertheless, quite apparent.

NOTE.—*A Modification of Smarmont's Process.*

In the case of stibnite, I have found that a thin layer of ammonium chloride, obtained by sublimation, answers well as a substitute for Senarmont's wax coating. The application of a heated point in the same manner as with gypsum, volatilises the salt, and leaves the surface of the crystal (cleavage plate) exposed. The resulting figures are clearly visible, but the specimens must of course be subsequently protected from injury in a glass tube or otherwise.

---

8. *A twin crystal of Sapphire.*

[Read June 20th, 1899.]

AMONG the specimens which have been recently added to the Oxford collection is a twin crystal of sapphire, of which it may be worth while to give a description in view of the rarity of well-formed twins of this mineral.

Digitized by Google

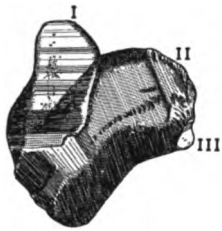


Fig. 1.

The crystal is shown about the natural size in the accompanying figure (Fig. 1); its weight is 10·23 grams. The two individuals are of somewhat unequal size, the largest (II) being 1 in. long by about ½ in. thick, the smaller (I) flattened and rather thinner. The edges are rounded and dull, as if worn by water, but portions of the faces still retain their original brilliant lustre.

The faces lie in the zones $[a, c] = [1\bar{1}0, 111]$, and are much striated. The front zone of (I) yields a series of angles which are arranged symmetrically on the two sides of a face $a(1\bar{1}0)$, (not present), and hence appear to correspond to definite faces—

$$\epsilon\{12.1.\bar{10}\}, \quad \mu\{10.1.\bar{8}\}, \quad \xi\{17.2.\bar{18}\}$$
$$\pi\{45.6.\bar{33}\}, \quad \sigma\{29.5.\bar{19}\}, \quad \tau\{14.3.\bar{8}\}$$

The indices are high, as is often the case with corundum, and the forms are all new. The angles are as follows, the mean of the readings for the best pair of faces (ξ) being taken to fix the position of (a)—

		Edges.	Limits.	Observed.	Calculated.[1]
$c : \epsilon$	$111 : 12.1.\bar{10}$	2	84°14′ – 84°21′	84°17½′	84°17′
$c : \mu$	$111 : 10.1.\bar{8}$	2	83 7 – 83 8	83 7½	83 1½
$c : \xi$	$111 : 17.2.\bar{18}$	1	—	81 48	81 39
$c : \pi$	$111 : 45.6.\bar{33}$	1	—	80 19	80 23
$c : \sigma$	$111 : 29.5.\bar{19}$	1	—	77 3	77 5
$c : \tau$	$111 : 14.3.\bar{8}$	1	—	73 17	73 17

At the back of (II) some small bright reentrant cleavage planes are visible, which may perhaps correspond to $n\{31\bar{1}\}$, and $\nu\{13.1.\bar{11}\}$, though no such cleavage or parting seems to have been recorded. The angles are :—

	Observed.	Calculated.
$c : n$ ...	61°17′ ...	61°11′
$c : \nu$ ...	84 48 ...	84 45½

The colour is pale blue, and traces of milky "ghosts," which are yellowish by transmitted light, are visible inside the crystals. There is a brilliant cleavage or parting, parallel to $r\{100\}$, and also a less perfect one, with silky lustre, parallel to the basal plane. A measure-

[1] Axial angle, $a = 85°47'$, $(a : c = 1 : 1·363)$.

Digitized by Google

ment on the goniometer of the angle between the *r*-cleavage of one individual and the basal cleavage of the other gave the values:—

$100 : \underline{\bar{1}\bar{1}\bar{1}} = \left\{\begin{matrix} 56°43' \\ 57°16' \\ 58°\ 5' \end{matrix}\right\}$, 3 (good) images being given by the basal plane.

The crystal is therefore twinned about the face (100), the calculated value of the above angle being 57°84′. This is the same twin law which governs the ordinary twin-lamellation of corundum. A small portion of a third individual (III) projects from the main crystal (II), and is proved by the rhombohedral cleavage to be parallel in position to (I).

The density is 3·989. A few small pieces of a greenish-black mineral are embedded in the crystal.

Etched pits, having the asymmetric form shown in Fig. 2, are present on some of the faces, and correspond—so far as can be judged from the upper half of the crystal, on which alone the pits occur—with the assumption of the rhombohedral symmetry of the calcite class.

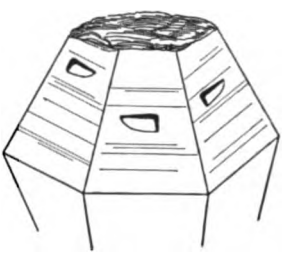


Fig. 2.

The locality of the specimen is uncertain, as it comes from an old collection, but it may probably be from Kashmir.

Twin crystals of sapphire have been previously described in a few cases:—

Jeremejeff, *Verh. k. russ. min. Ges.* (2), XIII, 426, 1877 [Abstr. *Zs. K.* II, 504].

Jeremejeff, *Verh. k. russ. min. Ges.* (2), XIV, 227, 1878 [Abstr. *Zs. K.* III, 488].

Jeremejeff, *Gornyi Journal*, III, 268, 1887 [Abstr. *Zs. K.* XV, 537].

Hidden and Washington, *Am. J. Sc.* (3), XXXIII, 507, 1887 [Abstr. *Zs. K.* XIV, 302].

Barvíř, *Ann. d. k.k. Hofmuseums*, Wien, VII, 135, 1892 [Abstr. *Zs. K.* XXV, 431].

The last observer describes and figures two crystals, of which one somewhat resembles the present specimen. The locality is given as "probably Ceylon."

I have also examined two specimens, kindly lent me by Mr. Francis Powell, which show a second small crystal projecting from the side of the main individual, and find that they are twins obeying the same law. In one of them a third small individual is twinned on the main crystal,

Digitized by Google

forming a triplet. It seems probable that many of the crystals of sapphire which have small knobs projecting from their surface may really be twins of this nature.

---

4. *On Monazite and associated minerals from Tintagel, Cornwall.*

[Read June 19th, 1900.]

IN the *Mineralogical Magazine*, Vol. VI, p. 164 (1885), Prof. Miers described a specimen in the British Museum, which carried crystals of monazite, dispersed on albite and quartz upon a silky slate, and in the absence of any label suggested that it probably came from Cornwall. Shortly after this he visited Tintagel, and in one of the large slate quarries there succeeded in finding a single crystal of monazite, very similar in appearance and association to those on the original specimen described by him.

In the Christmas Vacation of 1899, a small collecting party from Oxford visited the quarry at Tintagel, under the guidance of Prof. Miers, and our search was rewarded with four crystals of monazite and some good specimens of the associated minerals.

Of the numerous quarries in the neighbourhood in which albite and quartz are to be found, only one appears to yield monazite, namely, the large (though now but little worked) quarry about 1½ mile southwards along the coast from Tintagel Castle, which is marked on the 6 in. Ordnance map as "Lanterdan Quarry," but is locally known as part of "West Quarry."

The rock is a Devonian slate, which, just at this point, possesses a peculiar silky lustre. It is traversed by numerous straight joints running roughly in a N.E. and S.W. direction, which dip at a steep angle, and are lined with crystals of albite and quartz, and (in some places) calcite.

The monazite usually lies upon the albite in the joints, but one of the crystals found lies in a small secondary crack directly on the slate.

This Cornish occurrence of monazite offers no exception to the generalisation that this mineral is always accompanied by some form of TiO_2, for rutile is found along with it on the albite, and anatase occurs in the neighbouring "Lambshouse Quarry," a few hundred yards to the north.

Monazite.

Most of the crystals are of the common habit, forming rather thick tables parallel to *a*(100), and of a reddish-brown colour. The finest of these we obtained is about 2½ mm. long (*b*-axis), and shows the forms:—

Digitized by Google

$a\{100\}$; $w\{101\}$; $e\{011\}$; $i\{\bar{2}11\}$; $z\{\bar{3}11\}$; $r\{111\}$; $m\{110\}$; $q\{701\}$.

It is a twin upon the face $a(100)$, and appears to be more or less interpenetrant. The specimen on which it occurs consists of albite, with quartz and calcite and rutile needles. The form $q\{701\}$ was originally discovered by Miers on the specimen in the British Museum, and as it does not seem to have been again observed, its occurrence on the present crystal confirms his suggestion with regard to the locality of that specimen.

The crystal mentioned above as lying directly on the slate, differs from the others both in its colour (a darker brown) and its habit, which is quite exceptional. It is tabular parallel to $b(010)$, and lies on a face of this form. I have measured the angles of the exposed portion without detaching the crystal from the matrix, and find the following forms:—

$b\{010\}$; $u\{021\}$; $e\{011\}$; $v\{\bar{1}11\}$; $o\{\bar{1}21\}$; $m\{110\}$; $n\{120\}$; $\mu\{130\}$; $w\{101\}$; $r\{111\}$; $\eta\{\bar{1}32\}$; $\theta\{\bar{1}22\}$.

Of these, μ, η, θ are new, and are established by the following angles:—

			Edges.	Limits.	Observed.	Calculated.[1]
In the zone $[bnm]$	$b\,\mu$	010:130	2	19°56′—20°26′	20°11′	19°29½′
	$n\,\mu$	120:130	1	..	9° 0′	8°28½′
,, $[uv]$	$u\,\eta$	$02\bar{1}:13\bar{2}$	1	..	[17°][2]	16°34′
	$v\,\eta$	$11\bar{1}:13\bar{2}$	1	..	[22°15′][2]	22°56′
,, ,, $[ev]$	$e\,\theta$	$011:\bar{1}22$	1	..	20°58′	20°26½′
	$v\,\theta$	$\bar{1}11:\bar{1}22$	1	..	18°29′	18° 9½′
	$u\,\theta$	$021:\bar{1}22$	1	..	25°33′	25°16′

The new faces are all distinct, though small, and μ is particularly bright. This crystal is shown in the accompanying figure (Fig. 1).

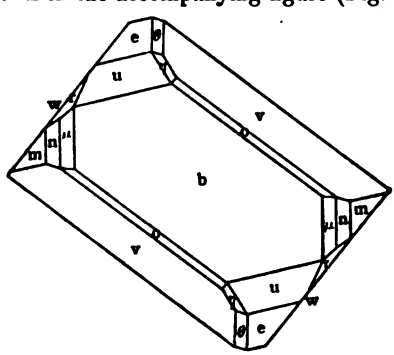


Fig. 1. Monazite.

[1] $a:b:c=0{\cdot}9693:1:0{\cdot}9256$ $\beta=76°20'$ (E. S. Dana.)

[2] Angles obtained by method of maximum illumination

Digitized by Google

Rutile.

The rutile found associated with the monazite is peculiar, as it forms very fine hair-like needles of a golden colour, lying quite loose upon the albite, and often matted together. Similar needles are also occasionally found enclosed in the quartz crystals.

Thin layers of rutile, of the same colour, and showing the "sagenite" structure, are also found in cracks in massive quartz in the same quarry along with chlorite.

Albite.

The albite occurs in good crystals, sometimes attaining a length (parallel to $x(\bar{1}01)$) of 2 cm., and often covers considerable areas of the faces of the joints. It is usually white, though sometimes stained with ochre, and the smaller crystals are often perfectly transparent.

The following forms are present:—

$b\{010\}$; $m\{110\}$; $M\{1\bar{1}0\}$; $z\{1\bar{3}0\}$; $c\{001\}$; $n\{0\bar{2}1\}$; $o\{\bar{1}\,\bar{1}1\}$; $\delta\{\bar{1}\,\bar{1}2\}$; $p\{\bar{1}11\}$; $x\{\bar{1}01\}$; $y\{\bar{2}01\}$.

Besides these, a small striated face (ξ) occurs on some crystals on the edge c/δ, making an angle of 3°—4° with the face c. The measurements are too uncertain to admit of the definite assignment of indices, but the form is not far from $\{\bar{1}.\bar{1}.16\}$, for which $c\xi = 3°22'$.

In sodium light, the extinction angles are—

On $c\{001\}$, somewhat variable, but usually about $+3°$ to 4°.

On $b\{010\}$, $+20°$.

These values would correspond to a nearly pure soda-felspar, as would also the emergence of a bisectrix through b, at a slight inclination to the normal.

Quartz.

The perfectly clear crystals of quartz, which mostly have a diameter of about 1 cm., but are also found considerably larger, occur with albite and calcite in nests along the joints. They are interesting on account of their commonly rhombohedral termination (the faces of $\{r\}$ being usually much larger than those of $\{z\}$), and from the frequency of twins.

Faces of $s\{4\bar{1}\bar{2}\}$ are very common, but $x\{4\bar{1}\bar{2}\}$ appears to be absent.

Twins according to two laws occur, viz.:—

(1) Rotation twins—twin axis $\perp c\{111\}$—(the common form).

(2) Reflection twins—of the kind described by Prof. Lewis as "laevo lextro-gyral, β"—which may be explained in a simple manner as inter-

Digitized by Google

penetration twins, of which the two individuals are related to one another by reflection over the equatorial plane.

Only two examples of the second law were obtained. They are represented in Fig. 2, and are characterised by the right- and left handed striation on the two halves of an *s* face.

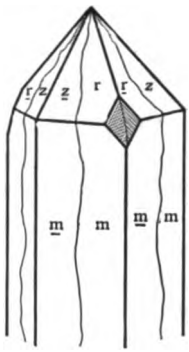


FIG. 2. Quartz twin.

Some of the crystals of quartz contain fine golden needles of rutile.

Pyrite.

On some of the specimens minute brown grains are to be seen on and among the needles of rutile, on which they are often strung like beads. These appear under the microscope to be very perfect model-like crystals of pyrite, showing a combination of a pyritohedron with the octahedron and narrow faces of the cube.

Striated cubic crystals of pyrite of larger size also occur embedded in the slate.

Calcite.

The calcite is always dull on the surface, and forms crystals from 1 to 4 cm. in diameter, the smaller being sharp, but the larger very coarse and rough. Owing to the dullness of the faces, it was necessary to cement small fragments of microscope cover-glass to them in order to obtain measurements. The latter are only approximate, owing to the difficulty of getting the covers to lie flat on the smaller faces. Hence it is impossible to be certain of the indices, which in calcite are often not simple, and in assigning probable indices I have assumed that the faces belong to the nearest form given in Irby's tables.

The smaller crystals are usually surrounded by an equatorial belt of flat plates resembling "schiefer spar," of very peculiar appearance, in parallel position. The basal planes of the schiefer spar, though much pitted and lying at different levels, are very brilliant, and yield a single perfect image of the goniometer signal.

Three habits may be distinguished :—

(1) Large, coarse, rounded crystals, apparently combinations of scalenohedra and rhombohedra.

(2) Rather flat scalenohedra (up to 2 cm. dia., but usually smaller), the points of which project from a bed of the schiefer spar, and are sometimes truncated by a small bright face of $c\{111\}$. The scalenohedron approximates to $\{310\}=\{21\bar{3}4\}$.

Digitized by Google

(3) Small scalenohedra, either near $v\{20\bar{1}\} = \{21\bar{3}1\}$, or differing somewhat from it—perhaps $\{46.\bar{5}.\bar{3}\bar{2}\} = \{17.9.\bar{2}\bar{6}.3\}$—, combined with an inverse rhombohedron, near $\epsilon\{22\bar{1}\} = \{01\bar{1}1\}$, and small faces of a very flat scalenohedron, perhaps $\{10.4.1\} = \{21\bar{3}5\}$, and possibly also $\{310\} = \{21\bar{3}4\}$.

Crystals of types (2) and (3) are very symmetrically developed. Some of those of (2) are twinned about $e\{011\} = \{\bar{1}012\}$, as is shown by the mutual inclination of the basal planes of the schiefer spar.

The calcite appears to be always associated with the quartz crystals and collected in definite nests, with or without albite, which latter is more abundant than either of the other two minerals. Rutile in fine needles occurs in these nests as well as on the albite alone.

Anatase (from Lambshouse Quarry).

This mineral occurs with small opaque white albite crystals, in small steel-blue octahedra (not exceeding 1 mm.), bounded by $p\{111\}$ and $k\{112\}$, striated and alternating with each other, with minute planes of $o\{107\}$ and $e\{101\}$.

This may probably be the locality mentioned by Greg and Lettsom for anatase, under the name "Tintagel Cliffs," though we did not find any of the "adularia" said by them to be associated with it.

Digitized by Google

Conchite, a new Form of Calcium Carbonate.[1]

By Agnes Kelly.

(Communicated by Prof. H. A. Miers.)

[Read June 19th, 1900.]

In the course of an investigation on calcareous secretions in the animal kingdom, and more particularly on molluscan shells, I found that the latter did not consist of aragonite, as G. Rose[2] and Sorby[3] had supposed, but of a negative, uniaxial mineral, which is distinguished by most of its properties from calcite, and for which I propose the name conchite (κόγχη, shell). I further found that conchite occurred naturally in many localities—always as a crystal aggregate. Its properties were investigated on such, as well as on the conchite in shells.

Chemical Composition.—Several shells consisting of conchite were analysed, both qualitatively and quantitatively. In Cardium edule, besides $CaCO_3$ and possible traces of NaCl, I found no inorganic constituent. The following percentages of CO_2 and CaO were determined:—

$CO_2 = 42{\cdot}45$ per cent.
$CaO = 54{\cdot}63$,,

97·08 per cent.

The remaining 2·92 per cent. was organic matter, which could not be determined directly. In Cyrena (sp ?) only CaO was determined, the calculated $CaCO_3$ was 97·2 per cent.

No quantitative analyses were made of naturally occurring conchite, but the various incrustations consisted mainly of $CaCO_3$; those formed under observation in kettles and water baths contained also traces of iron.

---

[1] A communication on conchite was laid before the Bavarian Academy on 5th May, 1900, and afterwards published in the *Sitzungsberichte der math.-phys. Classe* of that Academy.

[2] G. Rose, *Vorkommen des Aragonits und Kalkspaths in der organischen Natur*; *Abh. k. Akad. d. Wiss in Berlin*, 1858.

[3] Sorby, Presidential Address, *Quarterly Journal of the Geological Society*, 1879.

Digitized by Google

Solubility.—Conchite dissolves readily in acids, but it has not yet been shown by direct experiment whether it is more soluble than calcite or not. That it is certainly very much less stable than calcite under the action of atmospheric agencies is seen by comparing the behaviour of conchite and calcite-shells found as fossils. Sorby showed that in all older formations those shells only which he considered to be calcite were preserved as such, the others were either disintegrated or present as casts alone. I have been able to confirm most of Sorby's statements as to the presence of calcite; his aragonite shells are generally conchite, for no aragonite whatsoever is to be found in the animal kingdom. Cornish and Kendall[1] published a long list of the fossils found as shells or as casts in the Coralline Crag, stating that the shells were calcite, the casts aragonite. In this case also I have been able, for many of the genera mentioned, to demonstrate the calcite character of the one series, and the conchite character of the other series, by direct observation. In only one case, that of Serpula, does a fossil occur well preserved, which I have proved to consist of conchite.

The instability of conchite is further shown by Klement's[2] experiments on the artificial preparation of dolomite. Finely-powdered $CaCO_3$, together with crystalline magnesium sulphate and a saturated solution of NaCl, was heated in a closed retort to a constant temperature for a definite number of hours. The solution was then filtered and washed, and the percentage of $MgCO_3$ determined. Calcite heated for 10 hours to 100° gave traces only of $MgCO_3$; aragonite heated for 48 hours to 91° gave 34·6 per cent.; for 68 hours to 90°, 38 per cent. $MgCO_3$. Corals from a group in which I have been able to find conchite secretions only, gave:—Madrepora prolifera heated for 48 hours to 90° 38·5 per cent., Madrepora humilis 41·4 per cent. and Stylopora (sp?) 41·9 per cent. $MgCO_3$. Klement concluded that these corals consisted of aragonite, since conchite was unknown to him, but the increase in the amount of $MgCO_3$ formed in the experiment with the corals over that in the experiments with aragonite, indicate, quite apart from direct observation, that there is a still more unstable form of $CaCO_3$, this being conchite. Since all the important reef-building corals have skeletons of conchite, its instability and the possibility of its transformation into dolomite are of importance for the theory of the origin of dolomite.

---

[1] *Geological Magazine*, 1888, p. 66. "On the Mineralogical Constitution of Calcareous Organisms."

[2] Ueber die Bildung des Dolomit. *Tscherm. Min. Petr. Mitt.* 1895, XIV, 526.

Digitized by Google

Crystallisation from aqueous solution.—The conditions under which conchite crystallises out of water have not been determined with any exactitude. It was noticed, however, that in an apparatus used for obtaining distilled water, the spiral which was immersed in the ordinary hard tap water of Munich was thickly coated with $CaCO_3$ at the top, where it was hot, less thickly in the middle turns, where it was hardly warm to the touch, and was quite bare at the bottom, where the temperature was that of the water. The incrustations from the top and middle of the spiral consisted entirely of conchite, only the very lowest deposits contained some calcite as well.

On leaving solutions of calcium bicarbonate to evaporate at ordinary temperatures, calcite only was obtained, but at temperatures from 30° to 100° C. conchite in increasing proportions was also deposited. G. Rose, in his experiments on the artificial formation of aragonite, considered that the prisms formed under those conditions were aragonite. A careful examination of their properties, and especially the measurement of the index of refraction for the ordinary ray, shows them to be conchite. The prisms obtained on mixing boiling solutions of $CaCl_2$ and Na_2CO_3 or $NaHCO_3$ can similarly be shown to be conchite. I was able to examine only one deposit formed at a temperature markedly above 100° C., viz. an incrustation formed in a boiler under 7·5 atmospheres at 168° C., and it consisted entirely of aragonite, as proved by the biaxial interference figure.

We know little of the conditions of crystallisation of the calcareous secretions in the animal kingdom, but the following two points are noticeable :—

(1) The conditions under which calcite or conchite crystallises out seem to differ very slightly, for we get the outer layer of Pinna and Mytilus formed of calcite, the inner of conchite. Also in animals which secrete various calcareous structures we may get both varieties represented in the same animal, for example, Helix shell and Spiculum Amoris consist of conchite, its epiphragm and egg-shell of calcite; and Teredo has valves consisting of conchite and a tube of calcite.

(2) We cannot trace the influence of temperature as in deposition from bicarbonate solutions. In the secretions of cold-blooded animals, *i.e.* at ordinary air or water temperatures, we get on the whole more conchite than calcite. The only shells formed at comparatively high temperatures are bird's egg shells (about 37°C), and they are without exception calcite.

Digitized by Google

Though, like Vater,[1] I have so far been unable to obtain anything but calcite deposits from inorganic solutions at ordinary temperatures, the existence of conchite molluscan shells points to the possibility, under suitable conditions, of the deposition of conchite also at such temperatures.

Behaviour on heating.—Conchite resembles aragonite and ktypeite in being converted into calcite by heating, but differs from aragonite in undergoing the change at a considerably lower temperature.

This can be most readily demonstrated by parallel experiments; for example, in mercury vapour (360° C.) or in melting lead (325°) conchite is converted into calcite, but aragonite undergoes no change. Aragonite crystals break up between 373° and 380°, but only after heating to 405° was I able to see a uniaxial interference figure, and thus demonstrate the change.

Conchite begins to undergo the alteration between 300° and 310°, as can be proved by the occurrence of the twinned planes and cleavage characteristic of calcite. During the change the position of the principal axis is unaltered.

In aragonite and conchite we have two unstable forms of $CaCO_3$, as proved by the change which they undergo on heating, and in the case of aragonite by the greater solubility, as determined by Dr. H. W. Foote.[2] We have had indications that the solubility of conchite is also great, but exact measurements have yet to be made. The fact that up to 100° we get conchite as well as calcite crystallising out of solution, and at 168° aragonite only, is another instance of Ostwald's general statement in his *Grundriss der allgemeinen Chemie*, that on a change of condition and passage into a more stable one, not the variety of the substance which is most stable under the new conditions will tend to be formed, but that which is the least stable.

Specific Gravity.—Since only crystal aggregates were at my disposal there was always a tendency for the specific gravity to come out too low on account of porousness. The highest value obtained by a direct measurement was = 2·865 for an incrustation from a kettle. Crystal aggregates from Karlsbad and other incrustations from kettles and water baths were between 2·830 and 2·845. For Cyrena, from determinations of the specific gravity, the percentage of $CaCO_3$, and the specific gravity of organic matter, the value 2·874 was calculated.

---

[1] Ueber den Einfluss der Lösungsgenossen auf die Krystallisation des Calcium carbonats, *Theil II, Zeitsch. f. Kryst.* 1894, XXII, 209; *Theil IV*, 1895, XXIV, 378.

[2] *Z. f. Phys. Chemie*, 15th June, 1900. "Uber die physikalich-chemischen Beziehungen zwischen Aragonit und Calcit."

Digitized by Google

The hardness is considerably greater than that of calcite.

No *cleavage* was observed.

Optical Properties.—Conchite is uniaxial and negative like calcite. It is true that, more particularly in true nacreous layers, which invariably consist of conchite, a biaxial interference figure with a small optical angle is sometimes seen, although in general we have accurately uniaxial interference figures. Since nacreous layers consist of numbers of thin parallel lamellæ two possibilities are open—(1) that the mineral forming the nacreous layer is biaxial, and as in the case of uniaxial mica the uniaxial character is due to superposed lamellæ of equal thickness with all the principal axes parallel, but the secondary axes of successive lamellæ at right angles to one another; (2) that the mineral is uniaxial, and that the biaxial character is due to want of exact parallelism of the optical axes of the lamellæ. The reasons for thinking the second alternative the more probable are—

(1) The comparative rareness of the biaxial interference figure, and the want of constancy of the optical angle. In quite a small section of the shell of Cyclas cornea, for example, the angle varied considerably, and on examining a number of shells some were found to give accurately uniaxial interference figures.

(2) In sections through prismatic structures, such as the outer layer of Pandorina inæquivalvis, or the inner of Lithodomus dactylus or Chama macrophylla, and most inorganic incrustations, where there is no possibility of there being superposed lamellæ, the interference figure is always uniaxial.

The *indices of refraction* were determined for sodium light.

(*a*) By the *method of total reflection*. Since only crystal aggregates with the axes of the crystals more or less parallel, and no single crystals, were at my disposal, it was impossible to obtain very exact readings. Many observations were made by means of a prism (Wollaston method). The means for polished slabs of the following shells were:—Strombus gigas, $\epsilon = 1{\cdot}527$, $\omega = 1{\cdot}661$; Cyrena, $\epsilon = 1{\cdot}527$, $\omega = 1{\cdot}662$; Trigonia Lamarkii, $\epsilon = 1{\cdot}524$; Pinna squamosa (nacreous), $\epsilon = 1{\cdot}524$; Turbo sp.?; $\epsilon = 1{\cdot}527$.

Mr. W. J. Pope was kind enough to determine for me the values of ϵ for two shells by means of the Abbé Pulfrich Total-refractometer, and found for Strombus gigas $\epsilon = 1{\cdot}523$ and for Cyrena $\epsilon = 1{\cdot}526$.

Dr. Melczer also made some very careful readings for me by means of a similar instrument. A highly polished slab of Strombus gigas

Digitized by Google

was found to behave as a biaxial mineral with a small optical angle, the indices being $\alpha = 1{\cdot}523$, $\beta = 1{\cdot}659$, $\gamma = 1{\cdot}662$.

(*b*) *Microscopic Method.*—Prismatic crystals were examined under the microscope with one nicol. When parallel to the one arm of the cross wires, ϵ would have its minimum value; when parallel to the other arm, ω would be obtained. Two Thoulet's solutions were prepared, the first of such a concentration that its refractive index for sodium light was the same as ϵ, so that in sodium light, on focussing up or down, the crystal did not appear either lighter or darker than the solution; the second was similarly adjusted to equal ω. The refractive indices of the solutions were measured either directly on an Abbé's refractometer, or the specific gravity was measured and the refractive index calculated from Goldschmidt's tables. Both methods were found to agree to a unit in the third decimal place, so the latter as the simpler was usually resorted to.

The mean values obtained were $\epsilon = 1{\cdot}524$ and $\omega = 1{\cdot}661$.

Probably we may take these values as being correct to $\pm$ 1 in the 3rd decimal place, since they agree with the best values obtained by the method of total reflection.

The *birefringence* of conchite is accordingly considerably lower than that of calcite, about 0·187. This was also proved directly by observing sections of conchite and calcite of the same thickness in polarised light; for in sections parallel to the optic axis conchite shows colours of a lower order than calcite, and in sections perpendicular to the optic axis conchite shows fewer rings in its interference figure.

The *forms* in which conchite crystals may occur are as follows:—

(1) Prisms and acicular crystals. As such it is deposited from aqueous solutions on evaporation. The various naturally-occurring crystal aggregates all consist of prisms, and some shells, *e.g.* Pandorina inæquivalvis, consist in part of conchite prisms.

(2) Plates parallel to the base. This is the form in which the conchite of nacreous layers occurs.

(3) Rhombohedron-like crystals, with the long axis of the rhombohedron inclined at about 45° to the optical axis. They occur in Strombus and most other gastropods.

Occurrence of Conchite. Animal Kingdom.—A series of about 150 specimens, chosen from all the lime-secreting groups of the animal kingdom, was examined. That no aragonite is present is proved by the constant occurrence of uniaxial interference figures, by the value of ω not exceeding 1·661 (for aragonite $\beta_D = 1{\cdot}6816$, $\gamma_D = 1{\cdot}6859$), and by

Digitized by Google

the change to calcite at about 300°. The following tests were applied to distinguish between calcite and conchite.

(1) Specific gravity—calcite, 2·715; conchite, 2·87.

(2) Presence or absence of the twinning planes characteristic of calcite.

(3) Minimum value of ϵ—for calcite $\epsilon_D = 1{\cdot}486$; conchite $\epsilon_D = 1{\cdot}524$.

(4) Presence or absence of a change on heating.

As thus determined, the occurrence of conchite or calcite in the animal kingdom is as follows:—

Foraminifera, calcite.

Calcareous sponges, calcite.

Hydrocorallinæ, conchite.

Alcyonaria, calcite, except Heliopora, which is conchite.

Madreporaria, conchite.

Echinodermata, calcite.

Polyzoa, calcite.

Brachiopoda, calcite.

Mollusca. Lamellibranchiata.—Anomia, Ostrea, Pecten and the outermost layers of Pinna and Mytilus, calcite; all the rest conchite.

Gastropoda.—All conchite except Patella and Ianthine.

Opercula of Turbo and Nerita, conchite.

Cephalopoda and Scaphopoda, conchite.

Chætopoda.—Tube of Serpula, conchite.

Crustacea, calcite.

Egg shells of Bulimus, Helix, Alligator, and all birds, calcite; of Tortoise, conchite.

Otoliths of Gadus and Frog, conchite; of Sturgeon, calcite.

The same tests were applied to distinguish conchite in *inorganic nature*. It was found to occur in the following localities:—

Karlsbad, as the spheres in a pisolitic deposit. The spheres are considerably larger than those found to consist of ktypeite. Also as various varieties of Sprudelstein.

Schemnitz in Hungary, blue and brown incrustations.

Alt-sohl in Hungary, a brown incrustation.

Ringenwechsel near Schwatz in Tyrol, a blue incrustation.

Yellowstone Park, Sinter.

Various specimens of Flos Ferri were all found to be conchite, and the fur in kettles was generally conchite, sometimes with an admixture of calcite.

Amorphous Calcium Carbonate.

F. Linck showed that when $CaCO_3$ is precipitated it often appears first in the form of little spheres, which do not depolarise, and only later

Digitized by Google

become crystalline. If a calcium salt and a carbonate be allowed to diffuse into one another across a very viscid gum solution, such globules, together with crystals, may be obtained as a permanent preparation. As will be seen from their behaviour on heating, these globules constitute the most unstable of all the forms of $CaCO_3$, so that their appearance forms another case in illustration of Ostwald's generalisation, and one would indeed expect them to be precipitated first of all whenever the conditions were favourable. Whether they can crystallise afterwards as conchite, aragonite, or ktypeite or only as calcite is not known; the other unstable forms of $CaCO_3$ can all be converted by heat into calcite, but, so far as is known, never into each other. If the conversion of the globules into calcite is alone possible, their appearance would always condition the formation of calcite, and conchite, for example, could only be deposited when no globules had appeared.

I found in the course of these investigations that the calcium carbonate in the two posterior œsophageal glands of the earth-worm consists of just such globules in the amorphous condition. Moistened with water they very quickly become crystalline, but if they are dried at 100° and the last traces of water removed by treatment with absolute alcohol, they remain permanently amorphous.

Lowering the temperature has no action upon the globules; no change was called forth by leaving for several hours at the temperature of boiling water, but raising the temperature to only 160° to 170°C is enough to cause them to become crystalline.

An exact determination of the specific gravity was not possible, but by means of determinations of the specific gravity of the dried glands, of the organic substance, and of the percentage of $CaCO_3$, the specific gravity can be calculated to have the value 2·1. Similar determinations on the carapaces of Astacus and Julus gave values of 2·2, but these are still more inexact, for as well as about 50 per cent. $CaCO_3$, there is about 6 per cent. $Ca_3(PO_4)_2$ present.

The index of refraction was measured by the microscopic method, and found to be 1·538. Even under the highest magnification, and with the most sensitive methods, no action on polarised light could be observed.

Amorphous calcium carbonate occurs frequently in the animal kingdom, for example, as globules in the mucus of Helix, and not as globules in the carapaces of Astacus, Squilla, Julus and in the egg shell of the grass snake. On maceration with water or on heating it becomes crystalline, which explains why it is not found to occur as a mineral.

Digitized by Google

The alteration of Pyrite by underground water.

By John W. Evans, LL.B., D.Sc.,

Formerly State Geologist in Mysore.

[Read June 19th, 1900.]

IT has for many years been proposed to form a reservoir with an area of some 36 square kilometres for irrigation purposes near Hiriyur in Northern Mysore, by erecting a dam at Marikanave, where the River Vedavati or Hagari crosses a rocky ridge running north-north-west and south-south-east.

Doubts were raised as to whether the rock would form a sufficiently firm foundation, but Mr. Robert Bruce Foote, late Superintendent of the Geological Survey of India, and my predecessor as State Geologist in Mysore, reported that it was in every way suitable for the purpose. The engineers, however, were apprehensive that the water from the tank would penetrate into the rock below the dam, and disintegrate it in the same manner as the rock of the ridge, which has suffered considerable decomposition from the continued action of surface water during long periods of time. A committee was accordingly formed consisting of two engineers and two geologists, Mr. T. H. Holland, of the Geological Survey of India, and myself, to report on the subject.

An excavation had been made on the northern bank of the river, where it passes through the ridge. The unaltered rock was found at a depth of four or five metres below the level of the river in ordinary flood. The strata exposed appear to belong to the Dharwar formation, the earliest of the non-fossiliferous systems of southern India that shows evidence of a sedimentary origin. The beds at Marikanave consist of ferruginous schistose slates and chlorite schists striking parallel with the direction of the ridge. The cleavage and stratification, which are indistinguishable, are nearly vertical. The slate is the predominant rock, but chloritic bands are repeatedly interstratified with it. Both, but more especially the slate, contain a large amount of iron pyrite. Not only are laminæ of pyrite intercalated parallel to the stratification, but the joint planes are occupied by films of the same material. This is also widely disseminated through the substance of the rock, which was, however, found, when tested in its

Digitized by Google

unaltered condition, to possess more than the strength required by the engineers.

But in the ridge, and wherever the surface water had penetrated, the pyrite has been oxidised and removed. That in the joint planes was apparently first attacked, most of the iron was dissolved out, and only a little powdery ferric hydrate remained, which was soon washed away, and the rock became a mass of loose tile-like fragments. These, too, suffered decomposition, partly by the removal of the contained pyritic material, and partly as a result of the action of the sulphuric acid produced by the decomposition of the pyrite, sulphates of the bases in the rock being formed[1] and removed in solution, leaving only a certain amount of incoherent earthy material. The question for decision was whether underground water derived from the tank would ultimately have the same effect on the rocks below the dam.

Pyrite is of very frequent occurrence in the older rocks of the south of India. In many cases where they have been exposed to the action of surface weathering it has disappeared, the empty cavities which it once filled being the only indication of its former presence. Elsewhere, though the rock is quite unaltered in general character and apparently as strong as ever, the pyrite has been replaced by exact pseudomorphs in limonite, with or without cores of the original material.

It is at once obvious that the retention of the iron and the unaltered character of the rock must be due to the presence in the water, that effected the oxidation of the pyrite, of some substance that reacts with the sulphate of iron and sulphuric acid formed, so as to precipitate the iron and prevent the acid from corroding other parts of the rock. The only compounds likely to be present in any quantity that can produce this result are the carbonates of the alkaline earths and alkalis. As a general rule carbonate of lime must be the principal agent in the reaction.[2]

The changes that occur may be expressed by the equation :—

$$4FeS_2+15O_2+3H_2O+8CaCO_3=(Fe_2O_3)_2(H_2O)_3+8CaSO_4+8CO_2.$$

A simple calculation will show that the occurrence of complete pseudomorphs of limonite after pyrite implies the retention of the whole of the iron. The density of pyrite varies from 5·2 to 4·83. Four

[1] $FeS_2+H_2O+4O_2=FeSO_4+H_2SO_4$. A slight incrustation of hydrous aluminium sulphate was detected at one point by Mr. Holland. It is probable that sulphurous acid is at first formed, but is at once oxidised to sulphuric acid.

[2] The action of carbonates in promoting the formation of limonite from pyrite has been recognised by Dr. Justus Roth, *Allgemeine und Chemische Geologie*, I, pp. 235–236.

Digitized by Google

gramme molecules (each of 119·24 grammes) of pyrite will therefore occupy a space of $\frac{477}{5·2}$ to $\frac{477}{4·88}$—that is 92 to 99 cubic centimetres. Limonite has a density of from 4 to 3·6, so that one gramme molecule of the complex limonite combination, containing the same amount of iron as the four gramme molecules of pyrite, will occupy a space of 93 to 103 cubic centimetres, which is practically identical with the volume of the pyrite.[1]

If all the iron is to be retained in the pseudomorph, it is obviously necessary that the carbonates required to react with the iron and hydrogen sulphates formed by the oxidation of the pyrite should be present in the same water that provides the oxygen. The amount of oxygen soluble in water at 15° C. is about 30 litres per cubic metre. At normal pressure this will amount to 1·27 gramme molecules or 40·4 grammes of oxygen in a cubic metre, and will be enough to fully oxidise both the iron and the sulphur, as in the above equation, of ·339 gramme molecules of pyrite, and it will require twice that number of gramme molecules of carbonates (considered as normal carbonates and excluding carbonic anhydride in a free state or combined only with water), that is 40·4 grammes of the CO_3 group to react with the sulphates resulting from such oxidation.

The highest amount of oxygen in ordinary spring or river water among the analyses given in the 1877 edition of Watts's *Dictionary of Chemistry* under the article "Water" is only 11 litres per cubic metre.[2] The average is 7 litres.

The following table gives the details of the oxidising power of these quantities of dissolved oxygen and the carbonates required to react with the oxidised products[3]:—

---

[1] If the iron had been converted into hæmatite the volume would have been 60 to 65 cc.; if into magnetite 61 cc.; if into turgite 75 to 78; if into göthite 80 to 88; while if it had passed into xanthosiderite it would have exceeded in volume the limonite. Accordingly, if all the iron be retained and none added, limonite is the only oxide or hydrate of iron that can form exact pseudomorphs after pyrite. It seems possible that the amount of space available may sometimes determine the quantity of water which enters into combination with the ferric oxide.

[2] Among mineral waters one analysis gives 13 litres. The highest in Thorpe's *Dictionary of Applied Chemistry* is 7·26 litres (III, p. 964).

[3] The identity of the figures in the 4th and 7th columns is of course accidental.

Digitized by Google

	Oxygen in cubic metre.			Pyrite oxidised.	Sulphates formed and carbonates required.	CO_2 (as normal carbonate) required.
	litres.	gramme molecules.	grammes.	gramme molecules.	gramme molecules.	grammes.
Maximum oxygen soluble at 15° C. and 760 mm.	30	1·27	40·4	·34	·68	40·4
Maximum oxygen recorded in ordinary spring or river water	11	·47	14·8	·12	·25	14·8
Average oxygen in river and spring water	7	·30	9·4	·08	·16	9·4

Among the 89 analyses of spring and river water (excluding mineral waters) given in the same edition of Watts's *Dictionary of Chemistry*, 76 have more than 9·4 grammes of the CO_2 group (combined as above) per cubic metre, 74 more than 14·8 grammes, and 68 more than 40·4 grammes; the average being 127 grammes. There is therefore in most cases far more than the amount of carbonates required.

The percentage of oxygen in the water of the proposed reservoir would probably be rather less than the above average, both on account of the higher temperature and because of the lower pressure at a height of about 700 metres above sea level. The presence of limestone in the drainage area and the occurrence of calcareous concretions in the recent alluvium of the river leave no doubt that the reservoir would contain an ample amount of carbonates to ensure that any pyrite it might oxidise in its incipient penetration of the rock would be at once converted into compact limonite completely filling the same space, thereby preventing to a great extent the further extension of the action of the water and preserving the strength of the rock. It would at the same time neutralise any sulphuric acid formed which would otherwise have attacked and dissolved the bases present.

As a general rule none of the calcium sulphate formed will be deposited; for the amount resulting from the reaction above described would be insufficient to saturate the water even though it had been saturated with oxygen which was all employed in oxidising pyrite, and the whole of the carbonate reacting with the sulphate formed were calcium carbonate. In that case the calcium sulphate produced would amount to ·68 gramme molecules, or 92 grammes in a cubic metre of water—which is capable of dissolving as much as 2,591 grammes at 18°C. Gypsum is, however, occasionally found in pseudomorphs after

Digitized by Google

pyrite with or without a kernel of limonite. This is probably attributable to the slow evaporation of the water *in situ*.[1]

I have made a few simple experiments on the subject of this paper. I placed 1·060 grammes of powdered pyrite in a low beaker within a larger vessel containing distilled water which was frequently changed, mainly by means of a syphon which allowed the water to fall into the vessel, drop by drop, at intervals of a few seconds. After about four months of this treatment the pyrite was still bright, there being scarcely a trace of iron oxide present. There was however a loss of weight of ·0136 grammes—representing pyrite which had passed into solution as ferrous sulphate and sulphuric acid, the former being no doubt afterwards converted into ferric sulphate.

At the same time a practically identical amount (1·062 grammes) of similar powdered pyrite was placed in a beaker of the same shape, in a vessel containing New River water, which was renewed in the same manner as the distilled water. The former was, on titration, found to contain 161 grammes per cubic metre of the CO_3 group (combined with alkalis or alkaline earths, and estimated as normal carbonate). After the same period of treatment a considerable amount of hydrated ferric oxide, resembling limonite in appearance, was visible amongst the pyrite and on the sides of the beaker. As the liquid remaining was allowed to evaporate a little gypsum was also seen, but was easily dissolved out with distilled water. The total loss in weight, after the removal of the gypsum, was only ·0033 grammes, which represented the difference in weight between the pyrite decomposed and the ferric hydrate formed. If the whole of the iron in the pyrite which was decomposed were converted into a ferric hydrate having the composition of limonite, the loss in weight would theoretically amount to 22 per cent. of the pyrite decomposed. As the water was in both cases added drop by drop, and the vessels in which the experiments were conducted exposed to the air an equal amount of surface, which was large in proportion to the volume of the liquid, it is reasonable to suppose that the actual amount of oxygen present in solution was practically the same in the two experiments (being in excess of that usually found in spring or river water), and we may infer that the amount of pyrite oxidised was the same in each case. On the supposition that this was so, and that in the New River water all the iron of the decomposed pyrite remained as limonite, the theoretical loss in weight that might have been expected would work out as ·0030, which is closer to the figures

[1] Roth, *loc. cit.* p. 236.

Digitized by Google

actually obtained than would have been expected, taking into account the conditions under which the experiment was performed and the probably indefinite character of the hydrate produced.

In another series of experiments small fragments of marcasite were placed in a vessel of distilled water. At the end of two months they were only slightly tarnished, but had diminished in weight from 7·453 to 7·430 grammes. A slight film of ferric hydrate was visible on the surrounding glass. Similar fragments were placed in another vessel filled with water, in which lumps of calcium carbonate were also placed. In less than twenty-four hours ferric hydrate was visible on the glass in the immediate neighbourhood, and in two months a considerable amount had accumulated both on the fragments and round them. Similar results were obtained with almost equal facility when such fragments were placed in a vessel in which New River water was allowed to fall drop by drop.

Similar experiments were conducted with zinc blende, which received a brown coating in calcareous water, but was unaltered in distilled water. Copper pyrites in calcareous water was coated by a similar brown ferruginous film, which was however slightly iridescent. In distilled water it was unaltered, though traces of iron could be detected in the solution. Further action would no doubt have resulted in the formation of appreciable quantities of copper sulphate. In old copper workings near Shimoga, in the north of Mysore, the action of surface water has resulted in the formation of fine stalactites of copper sulphates.

No effect was observable in the case of galena in the brief space of two months during which the experiments lasted.

Kupfernickel, smaltite and mispickel were unaltered in water containing carbonate of lime.

In distilled water kupfernickel was coated with a green film, indicating the formation of annabergite. In the case of smaltite, a white powder, probably arsenic trioxide, was deposited round the specimen, which showed scarcely any perceptible traces of erythrine being formed. No change was perceptible in the case of mispickel. This was contrary to expectation; the mineral is extensively disseminated through the crystalline schists in Mysore, and under the action of surface water all the sulphur is oxidised, the iron is dissolved out as sulphate, and the sulphuric acid attacks and removes a large proportion of the bases of the rock, the final result being a soft earthy material strongly impregnated with yellowish and greenish arsenates of iron, which sometimes extends over a distance of hundreds of metres.

Digitized by Google

Conclusions.

Where sulphides are exposed to the action of water free from carbonates, they will usually be slowly removed in solution as sulphates. When sufficient carbonates are present, as is the case with nearly all spring and river water, we may expect metallic carbonates, hydrates and oxides to be formed. In the case of iron it is the hydrate which is normally the first product. Free carbonic anhydride plays apparently no part in the formation of oxides, hydrates and carbonates from sulphides. When carbonates are not present in the water acting on the rock, the sulphides will usually be oxidised and removed as sulphates. The action of distilled water on metallic arsenides results in the formation of arsenates, which are in most cases insoluble. The presence of carbonate of lime seems in this case to retard the action.

Digitized by Google

A List of New Mineral Names.

By L. J. Spencer, M.A., F.G.S.,

Assistant in the Mineral Department of the British Museum.

SINCE the publication, three years ago, of the first of these lists at the end of Volume XI of the *Mineralogical Magazine*, so many new mineral names have been given that a second list may be useful as a completion to Volume XII. In addition to names which have recently been published are a few earlier names which are not to be found in some of the larger works of reference. The numerous compounded chemical and mineral names for artificial substances prepared by Doelter, Lemberg, Thugutt and others, have, with one or two exceptions, been omitted.

Ægirine-augite. H. Rosenbusch, *Mikrosk. Physiogr.* 3rd Ed. 1892, I, 537; Rosenbusch-Iddings, 4th Ed. 1898, p. 257. Intermediate between augite and ægirite.

Ægirine-diopside. W. C. Brögger, *Skrifter Vid.-Selsk. Christiania*, I, *Math.-natur. Kl.* 1898, No. 6, p. 169. The same as ægirine-augite.

Alite. A. E. Törnebohm [*Ueber die Petrographie des Portland-Cements.* Stockholm, 1897, 34 pp.] *Neues Jahrb. Min.* 1899, I, Ref. 485; *Zeits. Kryst. Min.* 1900, XXXII, 610. Silicate and aluminate of calcium, $x(3CaO.SiO_2)+(9CaO.2Al_2O_3)$. Probably rhombic with hexagonal habit. An important constituent of Portland-cement clinkers; with it are smaller amounts of other crystalline substances of similar composition, namely, *belite*, *felite* and *celite*.

Allingite. A. Tschirch and E. Aweng [*Archiv f. Pharmacie*, 1894, CCXXXII, 660-688] *Journ. Chem. Soc. Abstracts*, 1895, LXVIII (i), 385. A variety of amber (succinite) from Switzerland.

Alumotrichite. (P. Groth, *Min.-Samml. Strassburg*, 1878, p. 257). White, fibrous. Chili. [Probably the same as kalinite].

Alumyte. G. H. Kinahan, *Journ. R. Geol. Soc. Ireland*, 1889, VIII, 66; *Trans. Manchester Geol. Soc.* 1895, XXIII, 165. Alum-clay ("bauxite") of Co. Antrim.

Digitized by Google

Ancylite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 49. Small yellow crystals of octahedral habit with curved faces. Rhombic.

$4Ce(OH)CO_3.3SrCO_3.3H_2O$. South Greenland.

Angolite. E. Breusing, *Neues Jahrb. Min.* 1900, *Beil.-Bd.* XIII, 265. Breithaupt's manganocalcite from Schemnitz was shown by Des Cloizeaux to be a mixture of carbonates with an anorthic hydrated silicate of manganese. To the latter the name *Angolith* is now given, and the composition assigned to it is $H_2Mn_3(SiO_3)_4+H_2O$. It appears to be a zeolite.

Argentopercylite. (*Chem.-Zeit.* 1892, XVI, 1952.) The same as boleite.

Arsenpolybasit. S. L. Penfield, *Zeits. Kryst. Min.* 1896, XXVII, 66. Arsenical polybasite = pearceite.

Arzrunite. A. Dannenberg, *Zeits. Kryst. Min.* 1899, XXXI, 230; Abstr. *Min. Mag.* XII, 308. A bright blue-green crystalline crust. $PbSO_4.PbO+3(CuCl_2.H_2O)+Cu(OH)_2$. Rhombic. Chili.

Baddeckite. G. C. Hoffmann, *Amer. J. Sci.* 1898, VI, 274; *Rept. Geol. Survey, Canada, for 1896*, 1898, IX, R 11. A copper-red, highly ferruginous variety of muscovite occurring as scales in clay near Baddeck, Nova Scotia.

Bardiglione. Comte de Bournon, *Trans. Geol. Soc.* 1811, I, 77. The same as anhydrite.

Barium-parisite. See cordylite.

Barracanite. R. Schneider, *Journ. prakt. Chem.* 1895, LII, 557. Those specimens of cubanite, from Barracanao, Cuba, which give the formula $CuFe_2S_4$, instead of $CuFe_3S_5$ as in the original cubanite. *Cupropyrite* is given as an alternative name.

Barytheulandit. *Neues Jahrb. Min.* 1898, I, Ref. 447. The same as barium heulandite.

Beaconite. M. E. Wadsworth, *Rept. State Board Geol. Survey, Michigan, for 1891-2*, 1893, p. 171. A fibrous variety of talc resembling asbestos, from Beacon, Michigan.

Beckerite. E. Pieszczek [*Archiv f. Pharmacie*, [iii], XIV, 433-6] *Journ. Chem. Soc. Abstracts*, 1881, XL, 687. A brown resin occurring with Prussian amber.

Belite. See under alite.

Digitized by Google

Bentonite. W. C. Knight, *Engineering and Mining Journ.* New York, 1898, LXVI, 491, 638. An impure clay occurring in the Fort Benton shales, Wyoming. Previously called *taylorite* (see below).

Beresowite. J. Samoiloff, *Bull. Soc. Nat. Moscou*, 1897, p. 290. *Beresovite*, Dana's Appendix, 1899. Indistinct dark red crystals resembling melanochroite. $2PbO.3PbCrO_4.PbCO_3$. Beresovsk, Urals.

Birmite. Dana's Appendix, 1899. The same as burmite.

Bitumenite. T. S. Traill, 1853, *Trans. R. Soc. Edinb.* 1857, XXI, 7. The same as torbanite. Groth (*Tab. Uebers. Min.* 2nd-4th Ed.) gives *bituminite*.

Blätterserpentin. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 135. Lamellar serpentine = antigorite.

Britholite. C. Winther, *Medd. om Grönland*, 1900, XXIV, 190. Rhombic; pseudohexagonal by twinning.

$3[4SiO_2.2(Ce,La,Di,Fe)_2O_3.3(Ca,Mg)O.H_2O.NaF].2[P_2O_5.Ce_2O_3]$.

S. Greenland.

Calcistrontite. Von der Marck, *Verh. Ver. Rheinl.* Bonn, 1882, XXXIX, Corr.-bl. 84. Supposed to be $3CaCO_3.2SrCO_3$, but shown by H. Laspeyres (*Zeits. Kryst. Min.* 1896, XXVII, 41) to be a mechanical mixture of calcite and strontianite. Westphalia.

Carnotite. C. Friedel and E. Cumenge, *Compt. Rend. Acad. Sci. Paris*, 1899, CXXVIII, 532; *Bull. Soc. Chim.* 1899, XXI, 328; *Bull. Soc. franç. Min.* 1899, XXII, pp. 26 and 26 *bis*; *Chem. News*, 1899, LXXX, 16. W. F. Hillebrand and F. L. Ransome, *Amer. J. Sci.* 1900, X, 120. A bright canary-yellow substance impregnating sandstone in Western Colorado. Friedel gives the composition as $2UO_3.V_2O_5.K_2O.3H_2O$, but Hillebrand shows it to be a mixture of minerals.

Catophorite. W. C. Brögger, *Die Eruptivgest. d. Kristianiagebietes, Skrifter Vid.-Selsk.* I, *Math.-natur. Kl.* 1894, No. 4, pp. 27-39, 73; 1898, No. 6, 169 *(Katoforit)*; Abstr. *Min. Mag.* XI. 115. Dana's Appendix, 1899, *Cataphorite*. A soda-iron amphibole between barkevikite and arfvedsonite in its optical characters. Occurs in the grorudite of the Christiania district. A. Osann, *Tsch. Min. Mitth.* 1896, XV, 450; Abstr. *Min. Mag.* XI, 250. Texas.

Cedarite. R. Klebs, *Jahrb. k. Preuss. geol. Landesanst. for 1896*, 1897, XVII (ii), 199. An amber-like resin from Cedar Lake, Canada, previously described under the name chemawinite.

Celite. See under alite.

Digitized by Google

Cementite. F. Osmond [*Bull. Soc. Encour. Indust. Paris*, 1895, X, 480] *Nature*, 1895, LII, 367; *Zeits. Kryst. Min.* 1896, XXVII, 538. A carbide of iron occurring in steel. Probably Fe_3C, and possibly identical with cohenite (Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 16). To various other microscopic constituents of steel have been given the names, *austenite*, *ferrite*, *martensite*, *perlite (pearlyte)*, *sorbite* and *troostite*.

Chalcolamprite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 160. A member of the pyrochlore group occurring as small regular octahedra with a metallic coppery lustre on the surface. $R''Nb_2O_6F_2+R''SiO_3$; (R=Ca,Zr,Na,Ce, etc.). S. Greenland. Compare endeiolite below.

Chlorarsenian. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 171. The same as chloroarsenian.

Churchillite. A. Dufrénoy, *Min.* 2nd Ed. 1856, III, 280. The same as mendipite. From Churchill, Mendip Hills.

Clinohedrite. (1). A. H. Chester, *Dictionary of the Names of Minerals*, 1896. Breithaupt's Clinoëdrit (=tetrahedrite).

(2). S. L. Penfield and H. W. Foote, *Amer. J. Sci.* 1898, V, 289; *Zeits. Kryst. Min.* 1899, XXX, 587 *(Klinoëdrit)*; Abstr. *Min. Mag.* XII, 133. Monoclinic, domatic class. $Zn(OH)Ca(OH)SiO_3$. Franklin Furnace, New Jersey.

Conchite. Agnes Kelly, *Nature*, 1900, LXII, 239; *Min. Mag.* 1900, XII, 363; *Sitz-Ber. Akad. München*, 1900, 187. A form of calcium carbonate; optically uniaxial and negative, but with higher refractive indices than calcite, and no cleavage or twinning. Occurs as various animal secretions (molluscs, &c.), the fur of kettles, and in the hot springs of Carlsbad, Bohemia.

Cordierite-pinite. H. Gemböck, *Zeits. Kryst. Min.* 1898, XXIX, 305; 1899, XXXI, 248. Pinite when derived from cordierite.

Cordylite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 42. Wax-yellow, club-shaped hexagonal crystals, isomorphous with parisite. $(CeF)_2Ba(CO_3)_3$. Also called *barium-parisite*. S. Greenland.

Courtzilite. (*17th Ann. Rept. U.S. Geol. Survey, 1895-6*, Part III, 752). A kind of asphaltum.

Cubeite. Dana's Appendix, 1899. See Kubeit.

Cubosilicite. L. Bombicci, *Mem. Accad. Sci. Bologna*, 1899 [v], VIII, 67. The smalt-blue cubes from Tresztya, Transylvania, usually supposed to be pseudomorphs of chalcedony after fluor, are considered to be a definite form of pseudo-cubic silica related to melanophlogite and cristobalite. [Compare guanabaquite.]

Digitized by Google

Cuprobinnite. A. Weisbach, *Char. Min.* 1880, p. 42. The same as binnite (=tennantite).

Cuprogoslarite. A. F. Rogers, *Kansas Univ. Quart.* 1899, VIII, A 105 *(Cupro-Goslarite)*. Cupriferous goslarite.

Cupropyrite. R. Schneider, *Journ. prakt. Chem.* 1895, LII, 557. An alternative name for barracanite (see above).

Cylindrite. A. H. Chester, *Dictionary of the Names of Minerals*, 1896. The same as kylindrite.

Darlingite. (*Trans. R. Soc. Victoria*, 1866, VII, 80; *Proc. R. Soc. Victoria*, 1897, N.S. IX, 86). A kind of lydian stone from Victoria.

Eastonite. (*The Mineral Collector*, New York, 1899, VI, 118.) A silver-white mica similar in composition to a vermiculite. Easton, Pennsylvania.

Elfestorpite. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 172. The same as elfstorpite.

Endeiolite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 166. A member of the pyrochlore group occurring in small regular octahedra. $R''Nb_2O_6(OH)_2.R''SiO_3$; (R″ = Ca,Na,Zr,Ce, etc.). S. Greenland. Compare chalcolamprite above.

Epistolite. O. B. Boeggild, *Medd. om Grönland*, 1900, XXIV, 188. Large thin rectangular plates with a perfect cleavage parallel to the large face which is silver-white with a strong pearly lustre. Monoclinic. $19SiO_2.4TiO_2.5Nb_2O_5.(Ca,Mg,Fe,Mn)O.10Na_2O.21H_2O.4NaF$.
South Greenland.

Erionite. A. S. Eakle, *Amer. J. Sci.* 1898, VI, 66; *Zeits. Kryst. Min.* 1898, XXX, 176. A zeolite occurring as fine woolly hairs. Rhombic. Chemical formula the same as that of stilbite, but with more alkalies and less lime. Oregon.

Erlan. A. Breithaupt, *Vollst. Char. Min.-Syst.* 1823, pp. 64, 208. Massive; green; a mixture of silicates. Erla, Saxony.

Euban. A. Breithaupt (P. Groth, *Min.-Samml. Strassburg*, 1878, 258). A variety of quartz from Euba, Saxony.

Euchlorine. Used by A. Scacchi at the Naples Museum for an emerald-green incrustation found in 1869 on Vesuvian lava. The textbooks of F. Pisani (1875, p. 338) and other French authors state that it is a chloride and sulphate of copper. The first complete description

Digitized by Google

(E. Scacchi, *Rend. Accad. Sci. Napoli*, 1884, XXIII, 159) gives it as rhombic with the composition $(K,Na)_2SO_4.2CuSO_4.CuO$. An analysis by Rammelsberg (*Min.-Chem. Erg.-Heft*, 1886, p. 87) gives the formula $4(K,Na)_2SO_4.6CuSO_4.3Cu(OH)_2$.

Faserserpentin. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 135. The same as chrysotile.

Fedorowite. C. Viola, *Neues Jahrb. Min.* 1899, I. 121. C. Viola and E. H. Kraus, *Zeits. Kryst. Min.* 1900, XXXIII, 36. *Fedorovite*, Dana's Appendix, 1899. A monoclinic pyroxene near diopside in chemical composition, but near ægirite in optical characters. In all kinds of igneous rocks in the province Rome.

Felite. See under alite.

Florencite. E. Hussak and G. T. Prior, *Nature*, 1899, LXI, 119; *Min. Mag.* 1900, XII, 244, 249. Pale yellow rhombohedral crystals.

$AlPO_4.CePO_4.Al_2(OH)_6$. Isomorphous with hamlinite. Brazil.

Fluor-herderite. S. L. Penfield, *Amer. J. Sci.* 1894, XLVII, 330. Herderite containing fluorine with little or no hydroxyl.

$Ca(BeF)PO_4$. See hydro-herderite.

Glaucamphiboles. H. Rosenbusch, *Sitz.-Ber. Akad. Berlin*, 1898, p. 707 (*Glaukamphibole*). A group-name to include the alkali-amphiboles, glaucophane, gastaldite, and crossite, which are of dynamo-metamorphic origin, as distinct from the arfvedsonite-amphiboles, arfvedsonite, riebeckite and hastingsite, which occur only as original constituents in igneous rocks.

Glaucochroite. S. L. Penfield and C. H. Warren, Dana's Appendix, 1899; *Amer. J. Sci.* 1899, VIII, 343; *Zeits. Kryst. Min.* 1900, XXXII, 231; Abstr. *Min. Mag.* XII, 316. A member of the olivine group occurring as embedded prismatic crystals with a bluish-green colour resembling beryl. Rhombic. $CaMnSiO_4$. Franklin Furnace, New Jersey.

Goldschmidtite. W. H. Hobbs, *Amer. J. Sci.* 1899, VII, 357; *Zeits. Kryst. Min.* 1899, XXXI, 417. A telluride of gold and silver, Au_2AgTe_6, intermediate between calaverite and sylvanite. Monoclinic. Cripple Creek district, Colorado.

Gonsogolite. (P. Groth, *Min.-Samml. Strassburg*, 1878, p. 258. *Gonsogolith.*) Probably the same as pectolite. Predazzo, Tyrol.

Digitized by Google

Graftonite. S. L. Penfield, *Amer. J. Sci.* 1900, IX, 20; *Zeits. Kryst. Min.* 1900, XXXII, 433. Indistinct monoclinic crystals, consisting of a fine lamellar intergrowth of light coloured graftonite with darker triphylite. $(Fe,Mn,Ca)_3P_2O_8$. Grafton, New Hampshire.

Grünlingite. W. Muthmann and E. Schröder, *Zeits. Kryst. Min.* 1897, XXIX, 144; Abstr. *Min. Mag.* XII, 45. The Cumberland mineral usually referred to tetradymite (or joseite) was found to have the composition Bi_4S_3Te, and therefore to differ from tetradymite. Probably rhombohedral.

Gunnarite. G. Landström, *Geol. För. Förh.* 1887, IX, 368. $3FeS_2.2NiS$. Probably identical with pentlandite (Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 20). Sweden.

Hancockite. S. L. Penfield and C. H. Warren, Dana's Appendix, 1899; *Amer. J. Sci.* 1899, VIII, 339; *Zeits. Kryst. Min.* 1900, XXXII, 228; Abstr. *Min. Mag.* XII, 316. A member of the epidote group occurring as brownish red cellular masses of minute lath-shaped crystals. Monoclinic. $R''_2(R'''.OH)R'''_2(SiO_4)_3$; ($R''' = Al,Fe,Mn$; $R'' = Pb,Ca,Mn$). Franklin Furnace, New Jersey.

Hardystonite. J. E. Wolff, *Proc. Amer. Acad. Arts and Sci.* 1899, XXXIV, 479; *Zeits. Kryst. Min.* 1899, XXXII, 1; 1900, XXXIII, 147; Abstr. *Min. Mag.* XII, 315. White granular masses. Tetragonal. $ZnCa_2Si_2O_7$. Franklin Furnace, New Jersey.

Hyaloallophane. G. D'Achiardi, *Atti Soc. Toscana Sci. Nat.* 1898, *Proc. Verb.* XII, 32 *(Jaloallofane)*. Allophane containing an excess of silica, supposed to be due to the presence of admixed hyalite (=jalite in Italian). Sardinia.

Hydro-fluor-herderite. S. L. Penfield, *Amer. J. Sci.* 1894, XLVII, 330. Herderite containing both fluorine and hydroxyl.
$Ca[Be(OH,F)]PO_4$.

Hydrogoethite. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 48. $3Fe_2O_3.4H_2O$. Represents a stage in the alteration of göthite to limonite, as hydrohæmatite (=turgite) is a stage between hæmatite and göthite.

Hydro-herderite. S. L. Penfield, *Amer. J. Sci.* 1894, XLVII, 330. Herderite containing hydroxyl in place of fluorine.
$Ca[Be(OH)]PO_4$. See fluor-herderite.

Hydrolite. G. Mackenzie (T. Allan, *Min. Nomencl.* 3rd Ed. 1819). The same as siliceous sinter.

Digitized by Google

Hydrophlogopite. (W. F. Clarke, *Bull. U.S. Geol. Survey*, 1895, No. 125, p. 49; P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 131). Contains less alkalies and more loosely combined water than phlogopite.

Jaloallofane. See hyaloallophane.

Jocketan. A. Breithaupt (A. Frenzel, *Min. Lexicon Sachsen*, 1874, p. 160). Hydrated carbonate of iron occurring as concretions on limonite. Jocketa, Saxony.

Johnstonite. E. J. Chapman, *Min.* 1843, p. 42. The same as vanadanite.

Johnstonotite. W. A. Macleod and O. E. White, *Papers and Proc. R. Soc. Tasmania, for 1898-9*, 1900, p. 74. A variety of garnet. Named after R. M. Johnston.

Kalgoorlite. E. F. Pittman, *Records Geol. Survey, New South Wales*, 1898, V, 203. Massive, iron-black. $HgAu_2Ag_6Te_6$. Kalgoorlie, Western Australia.

Katoforit. See catophorite.

Kieselmagnesite. (P. Groth, *Tab. Uebers. Min.* 3rd Ed. 1889, p. 52). A compact mixture of magnesite and quartz.

Kietyöite. A. E. Nordenskiöld, *Min. Finland*, 1863, p. 154. Apatite from Kietyö, Finland.

Klinoëdrit. See clinohedrite.

Kochenite. A. Pichler, *Jahrb. geol. Reichs. Wien*, 1863, XVIII, 47; V. von Zepharovich, *Min. Lexicon Oesterr.* 1873, II, 170. A fossil amber-like resin from Kochenthal, Tyrol.

Kordylite. See Cordylite.

Kosmochromit. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 132. The same as kosmochlor.

Kryptomerite. (P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 172). A doubtful borate.

Ktypeite. A. Lacroix, *Compt. Rend. Acad. Sci. Paris*, 1898, CXXVI, 602. H. Vater, *Verh. Ges. Deutsch. Naturf. u. Aerzte, 71 Versamml. zu München, 1899*, 1900, II (i), p. 188 (artificial). A form of calcium carbonate. Optically positive and sometimes biaxial; birefringence much less than in calcite and aragonite. Occurs as pisolites at Carlsbad, Bohemia, and in Algeria. (Compare conchite above).

Digitized by Google

Kubeit. L. Darapsky, *Neues Jahrb. Min.* 1898, I, 163; 1898, II, Ref. 366. A misprint for rubrite.

Lagoriolite. J. Morozewicz, *Tsch. Min. Mitth.* 1898, XVIII, 147 *(Lagoriolith; Natrongranat)*; Abstr. *Min. Mag.* XII, 314. An artificial soda-garnet with the formula $3(Na_2,Ca)O.Al_2O_3.3SiO_2$. Forms a connecting link between the garnet and nosean groups.

Lamprophyllite. W. Ramsay and V. Hackman [*Fennia, Bull. Soc. Géographie de Finlande*, 1894, XI, No. 2, p. 119] *Neues Jahrb. Min.* 1896, I, Ref. 259; Dana's Appendix, 1899. A mineral, related to astrophyllite, occurring in the nepheline-syenite of the Kola peninsula, Russian Lapland.

Lasur-oligoclase. P. von Jeremééff [Jubilee volume of the St. Petersburg Mining Institute, 1873, Part II, p. 167] *Zeits. Kryst. Min.* 1900, XXXII, 493 *(Lasur-Oligoklas)*. Nordenskiöld's "Lasur-Feldspath" from Lake Baikal is shown to have the crystal elements of oligoclase.

Leucophœnicite. S. L. Penfield and C. H. Warren, *Amer. J. Sci.* 1899, VIII, 351; *Zeits. Kryst. Min.* 1900, XXXII, 239 *(Leukophönicit)*; Abstr. *Min. Mag.* XII, 316. Purplish red to raspberry-coloured crystalline masses. A manganese humite with hydroxyl in place of fluorine. $R_5(R.OH)_2(SiO_4)_3$; (R = Mn,Zn,Ca). Probably monoclinic. Franklin Furnace, New Jersey.

Leucosphenite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 137. White prismatic crystals with wedge-shaped terminations. Monoclinic. $BaNa_4(TiO)_2(Si_2O_5)_5$. South Greenland.

Libollite. J. P. Gomes, *Comm. Dir. Trab. Geol. Portugal*, 1898, III, 240, 290. An asphaltum, resembling albertite, from Libollo, Portuguese West Africa.

Loranskite. M. P. Melnikoff [separate publication, St. Petersburg]; P. D. Nikolaéeff, *Verh. k. russ. min. Ges.* 1897 [ii], XXXV, Protocolle, p. 11; K. Flug, *ibid.* p. 30; Abstracts in *Zeits. Kryst. Min.* 1899, XXXI, 505. A massive black mineral containing Ta_2O_5,ZrO_2,Y earths, etc. Finland.

Lorenzenite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 130. [illegible] acicular rhombic crystals with high adamantine lustre; sometimes [illegible]s with black tips. $Na_2O.2(Ti,Zr)O_2.2SiO_2$. South Greenland.

Digitized by Google

Lutécine. A. Michel-Lévy and Munier-Chalmas, *Bull. Soc. franç. Min.* 1892, XV, 175. The elements which build up the groupings called lutécite.

Manganberzeliite. L. J. Igelström, *Zeits. Kryst. Min.* 1894, XXIII, 593. The same as pyrrhoarsenite.

Manganglauconite. See marsjatskite.

Manjak. (R. P. Rothwell's *Mineral Industry* for 1897, New York, 1898, VI, 54; 1899, VII, 72. *Trans. Fed. Inst. Mining Eng.* 1898, XIV, 539; XVI, 33, 388). A local name for asphaltum from Barbados, West Indies.

Marsjatskite. E. von Fedorow and W. Nikitin, *Ann. Géol. Min. Russie*, 1899, III, 90, 102. Glauconite containing much manganese (*Manganglaukonit*); it forms the bulk of a Tertiary sandstone in the Marsjat forest, Urals.

Mayberyite. S. F. Peckham, *Journ. Franklin Inst.* 1895, CXL, 382. Named after C. F. Mabery (not Maybery). The names *mayberyite*, *venturaite* and *warrenite* are proposed in connection with a suggested new classification of petroleum, bitumen, etc.

Melite. F. Zambonini, *Zeits. Kryst. Min.* 1899, XXXII, 161. Hydrated silicate of Al,Fe. Massive. Thuringia.

Metaheulandite. F. Rinne, *Neues Jahrb. Min.* 1899, I, 18, 80. Heulandite from which part of the water has been artificially expelled, causing a variation in the optical characters (Abstr. *Min. Mag.* XII, 312).

Miersite. L. J. Spencer, *Nature*, 1898, LVII, 574. A cubic-tetrahedral modification of silver iodide containing some copper iodide; isomorphous with marshite. Broken Hill, New South Wales.

Mitchellite. J. H. Pratt, *Amer. J. Sci.* 1899, VII, 286. A variety of chromite containing much $MgO.Al_2O_3$. North Carolina. The same as magnochromite.

Moldovite. C. Istrati, *Bull. Soc. Sci. Bucarest*, 1897, VI, 91. A variety of ozocerite from Moldova (Moldavia).

Moronite. S. Calderon and M. Paul, *Anal. Soc. Espaü. Hist. Nat.* 1886, XV, 477. S. Calderon, *ibid.* 1894, XXIII, 21. A mixed siliceous and calcareous deposit formed of radiolaria, diatoms, foraminifera, &c. Moron, Spain.

Digitized by Google

Mossite. W. C. Brögger, *Skrifter Vid.-Selsk. Christiania*, I, *Math.-natur. Kl.* 1897, No. 7; Abstr. *Min. Mag.* XII, 130. Black tetragonal crystals twinned so as to simulate simple rhombic crystals of prismatic habit. $FeNb_2O_6.FeTa_2O_6$. Isomorphous with tapiolite. Moss, Norway.

Müllerite. F. Zambonini, *Zeits. Kryst. Min.* 1899, XXXII, 157. Yellowish green, soft and compact. $Fe_2O_3.3SiO_2+2H_2O$. Nontron, France. Differs from chloropal (nontronite) in having $2H_2O$ instead of $5H_2O$.

Muschketowite. E. von Fedorow and W. Nikitin, *Ann. Géol. Min. Russie*, 1899, III, 87, 99. A pseudomorph of magnetite after hæmatite. Urals.

Narsarsukite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 154. Honey-yellow tabular or cube-shaped tetragonal crystals.
$3Na_2O.Fe'''F.2TiO_2.12SiO_2$. Narsarsuk, S. Greenland.

Nasonite. S. L. Penfield and C. H. Warren, Dana's Appendix, 1899; *Amer. J. Sci.* 1899, VIII, 346; *Zeits. Kryst. Min.* 1900, XXXII, 284; Abstr. *Min. Mag.* XII, 316. White, massive. $Pb_4(PbCl)'_2Ca_4(Si_2O_7)_3$. Probably tetragonal and isomorphous with ganomalite. Franklin Furnace, New Jersey.

Natronanorthite. S. J. Thugutt, *Neues Jahrb. Min.* 1895. *Beil.-Bd.* IX, 561. Abstr. *Min. Mag.* XI, 111, *soda-anorthite.* An artificial compound, $Na_2Al_2Si_2O_8$.

Natroncatapleiite. G. Flink, *Geol. För. Förh.* 1898, XV, 206; *Zeits. Kryst. Min.* 1894, XXIII, 359 *(Natronkatapleït).* Catapleiite containing soda in place of lime.

Natrongranat. See lagoriolite.

Natronmelilith. W. C. Brögger, *Eruptivgest. d. Kristianiagebiets, Skrifter Vid.-Selsk. Christiania*, I, *Math.-natur. Kl.* 1898, No. 6, pp. 69, 366. A tetragonal silicate of Al and Na belonging to the melilite or to the scapolite group. Occurs in the rock called farrisite; Christiania district.

Natronmikroklin. W. C. Brögger, *Die Silur. Etag. Kristianiagebiet*, 1882, p. 262; *Skrifter Vid.-Selsk. Christiania*, I, *Math.-natur. Kl.* 1898, No. 6, p. 11. Dana's Appendix, 1899, p. 5, *soda-microcline.* ne as anorthoclase.

a. C. A. Peterson, *20th Ann. Rept. U.S. Geol. Survey*, 1899, 7. A kind of asphaltum from Utah.

Digitized by Google

Osmite. R. Hermann, *Bull. Soc. Nat. Moscou*, 1836, IX, 228. Iridosmine with 40·83 per cent. of osmium.

Pantellarite. (A. Dufrénoy, *Min.* 1859, IV, 59 *(pontellarite)*; A. Des Cloizeaux, *Min.* 1862, I, 323). The felspar of Pantellaria analysed by Abich in 1840; since called anorthoclase.

Paragite. V. von Zepharovich, *Min. Lexicon Oesterr.* 1873, II, 350. The same as Korallenerz (corallinerz, Dana) or hepatic cinnabar, an ore of mercury in Idria.

Paralaurionite. G. F. H. Smith, *Min. Mag.* 1899, XII, 108, 183; *Zeits. Kryst. Min.* 1900, XXXII, 217. Dimorphous with laurionite, PbClOH. Monoclinic. In Roman lead slags from Laurion, Greece. See rafaelite.

Parianite. S. F. Peckham, *Journ. Franklin Inst.* 1895, CXL, 381. Asphaltum from the Pitch Lake of Trinidad.

Parorthoclase. F. Zirkel, *Lehrb. d. Petrogr.* 1893, I, 238 *(Parorthoklas)*. The same as anorthoclase.

Pelionite. W. F. Petterd, *Catalogue of the Minerals of Tasmania, Papers and Proc. R. Soc. Tasmania, for 1893*, 1894, p. 13. Cannel coal from Mount Pelion.

Philipstadite. R. A. Daly, *Proc. Amer. Acad. Arts and Sci.* 1899, XXXIV, 433; *Bull. Soc. franç. Min.* 1899, XXII, 144. A variety of hornblende from Philipstad, Sweden.

Picroilmenite. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 143 *(Pikroilmenit)*. The same as picrotitanite, a variety of ilmenite rich in magnesium.

Pietricikite. C. Istrati, *Bull. Soc. Sci. Bucarest*, 1897, VI, 65, 93. The correct spelling of Dana's zietrisikite. A variety of ozocerite from Mount Pietricica, Moldavia.

Pilite. E. Schulze, *Lithia Hercynica*, Leipzig, 1895, p. 29. The same as tinder-ore (Zundererz). Formula given as $Pb_3Sb_3S_8$, Harz.

Planoferrite. L. Darapsky, *Verh. deutsch. wiss. Ver. Santiago, Chili*, 1897, III, 423; *Bol. Soc. Nac. Mineria, Santiago*, 1898 [iii], X, 106; *Zeits. Kryst. Min.* 1898, XXIX, 213. Probably rhombic (F. Grünling). $Fe_2O_3.SO_3.15H_2O$. Groth (*Tab. Uebers. Min.* 4th Ed. 1898, p. 74) writes the formula as $SO_4Fe_2(OH)_4+13H_2O$. Chili.

Digitized by Google

Plumbobinnite. A. Weisbach, *Char. Min.* 1880, p. 42. The same as dufrenoysite.

Plusinglanz. A. Breithaupt, *Vollst. Char. Min.-Syst.* 1823, p. 277. Shown by A. Frenzel (*Tsch. Min. Mitth.* 1900, XIX, 244) to be identical with argyrodite.

Prasochrome. X. Landerer, *Neues Jahrb. Min.* 1850, 813, 682. A dark green alteration product coating chromite. Grecian Archipelago.

Přilepite. E. Bořický, Zepharovich's *Min. Lexicon Oesterr.* 1873, II, 246. A resinous substance occurring as reniform crusts on coal shales at Přilep, Bohemia.

Pseudo-chalcedonite. A. Lacroix, *Compt. Rend. Acad. Sci. Paris*, 1900, CXXX, 430. A form of fibrous anhydrous silica; optically biaxial and negative.

Pseudogaylussite. F. J. P. van Calker, *Zeits. Kryst. Min.* 1897, XXVIII, 556. The "barley corn" pseudomorphs of calcite after gaylussite (or celestite?).

Pseudo-ozocerite. Förtsch, *Zeits. f. Naturwiss. Ver. f. Sachsen u. Thüringen*, 1898, LXX, 322. Ozocerite from Central Persia, differing in some respects from Galician ozocerite.

Pseudoparisite. G. Flink, *Medd. om Grönland*, 1898, XIV, pp. 236 and iii; 1900, XXIV, 179. The same as cordylite (see above).

Pungernite. Bulgarine, *Quart. Journ. Geol. Soc.* 1851, VII, 66. Yellowish brown organic matter from the Silurian of Russia.

Pyraphrolith. (P. Groth, *Tab. Uebers. Min.* 3rd Ed. 1889, p. 156). A mixture of felspar and opal.

Rafaelite. A. Arzruni, *Zeits. Kryst. Min.* 1899, XXXI, 243 *(Rafaëlit)*; Abstr. *Min. Mag.* XII, 308. G. F. H. Smith, *Min. Mag.* 1899, XII, 183; *Zeits. Kryst. Min.* 1900, XXXII, 217. Identical with paralaurionite (see above). San Rafael mine, Chili.

Raspite. C. Hlawatsch, *Ann. naturh. Hofmus, Wien*, 1897, XII, 33; *Zeits. Kryst. Min.* 1897, XXIX, 130; 1899, XXXI, 1; *Records Geol. Survey, New South Wales.* 1898, VI, 51; Abstr. *Min. Mag.* XII, 47. Small yellow or brownish crystals with high adamantine lustre. Dimorphous, with stolzite, $PbWO_4$. Monoclinic. Broken Hill, New South Wales.

Digitized by Google

Rhodolite. W. E. Hidden and J. H. Pratt, *Amer. J. Sci.* 1898, V, 294; VI, 463; *Min. Mag.* 1899, XII, 133, 145. Garnet ("*rose garnet*") of a rose-red or rhododendron-red colour used as a gem-stone. $2Mg_3Al_2(SiO_4)_3 + Fe_3Al_2(SiO_4)_3$. North Carolina.

Robellazite. E. Cumenge, *Bull. Soc. franç. Min.* 1900, XXIII, 17. Black concretionary masses occurring with carnotite in Colorado. Contains V,Nb,Ta,W,Al,Fe,Mn.

Rose garnet. See rhodolite.

Rosenite. C. Zincken, *Pogg. Ann.* 1835, XXXV, 357. The same as plagionite.

Rosstrevorite. (Greg and Lettsom, *Min. of Great Brit.* 1858, p. 105.) Fibrous stellated epidote from near Rosstrevor, Co. Down.

Roumanite. C. Istrati [*Bull. Soc. Sci. Fizice*, 1895, IV, 59; *Anal. Acad. Române*, 1895, XVI] *Bull. Soc. Sci. Bucarest*, 1897, VI, 55; 1898, VII, 272. The same as rumänite.

Sauconite. W. T. Roepper, F. A. Genth's *Mineralogy of Pennsylvania*, 1875, p. 120. A zinciferous clay from Saucon Valley, Pennsylvania. (Analysis in Dana's 5th Edit. 1868, p. 409.)

Schizolite. C. Winther, *Medd. om Grönland*, 1900, XXIV, 196. A variety of pectolite, containing much manganese, occurring as pink prismatic crystals. Monoclinic. S. Greenland. Compare manganopectolite.

Senaite. E. Hussak and G. T. Prior, *Min. Mag.* 1898, XII, 80. Black crystals with the same symmetry as ilmenite (rhombohedral with parallel-faced hemihedrism), to which the mineral is related.
$(Fe,Pb)O.2(Ti,Mn)O_2$. Brazil.

Soda-anorthite. See natronanorthite.

Soda-catapleiite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 100. See natroncatapleiite.

Soda-garnet. See lagoriolite.

Soda-microcline. See natronmikroklin.

Spodiophyllite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 85. Rough, ash-grey, hexagonal prisms with the physical characters of chlorite, but containing no water. $(Al,Fe)_2(Mg,Fe,Mn)_3(Na_2,K_2)_2Si_5O_{24}$. South Greenland.

Digitized by Google

Staalerts. C. A. Münster, *Nyt Mag. f. Naturv.* 1892, XXXII, 269; *Skrifter Vid.-Selsk. Christiania*, I, *Math.-natur. Kl.* 1894, No. 1, p. 54. A massive steel grey ore which may be "arsenical silver" or argentiferous mispickel. Kongsberg, Norway. *Staalerts* (Norwegian) = *Stahlerz* (Germ.) = *Steel-ore* (Engl.).

Stantienite. E. Pieszczek [*Archiv f. Pharmacie*, [iii], XIV, 433-6] *Journ. Chem. Soc. Abstracts*, 1881, XL, 687. A black resin occurring with Prussian amber.

Stelznerite. A. Arzruni, *Zeits. Kryst. Min.* 1899, XXXI, 232; Abstr. *Min. Mag.* XII, 308. Green, transparent, prismatic crystals resembling brochantite in appearance. Rhombic. $CuSO_4.2Cu(OH)_2$. Chili.

Stokesite. A. Hutchinson, *Phil. Mag.* 1899, [v], XLVIII, 480; *Proc. Cambridge Phil. Soc.* 1900, X, 216; *Min. Mag.* 1900, XII, 274. A colourless crystal with the habit of gypsum. Rhombic.

$CaO.SnO_2.3SiO_2.2H_2O$. Cornwall.

Striegovite. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 135. The same as strigovite.

Sulphoborite. *Journ. Chem. Soc. Abstracts*, 1893, LXIV (i), 325. The same as sulfoborite.

Sulvanite. G. A. Goyder, *Trans. R. Soc. South Australia*, 1900, XXIV, 69; *Journ. Chem. Soc. Trans.* 1900, LXXVII, 1094. Sulphovanadate of copper, $3Cu_2S.V_2S_5$. Massive; bronze-yellow with metallic lustre. S. Australia.

Szaskaite. (T. A. Readwin, *Index to Mineralogy*, 1867.) The same as calamine ($ZnCO_3$). Szaska, Hungary.

Szechenyiite. J. A. Krenner, *Scientific Results of Count Béla Széchenyi's Travels in Eastern Asia*, Budapest, 1897, III, p. 290 (Hungarian); Abstr. in *Zeits. Kryst. Min.* 1899, XXXI, 503. A soda-amphibole resembling diallage in appearance.

$2Na_2O.10MgO.3CaO.Al_2O_3.16SiO_2$. Occurs embedded in jadeite from Burma.

Tainiolite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 115. A mica occurring in the form of strips. Monoclinic.

$(MgOH)_2(K,Na,Li)Si_3O_8 + H_2O$. South Greenland.

Taylorite. W. C. Knight, *Engineering and Mining Journ.* New York, 1897, LXIII, 600. An impure clay from Wyoming. The name afterwards changed to *bentonite* (see above).

Digitized by Google

Teruelite. A. Maestre, *Anales de Minas, Madrid*, 1845, III, 264; F. Quiroga, *Anal. Soc. Españ. Hist. Nat.* 1873, II, 249; F. Chaves, *Anal. Soc. Españ. Hist. Nat.* 1891, XX, Actas p. 9. Black, acute rhombohedra (with basal planes) of dolomite from Teruel, Aragon.

Thalenite. C. Benedicks, *Geol. För. Förh.* 1898, XX, 308; *Bull. Geol. Inst. Univ. Upsala*, 1899 (for 1898), IV, 1 *(Thalénit)*. Flesh-red; massive and in dull monoclinic crystals. $H_2O.2Y_2O_3.4SiO_2$.
Österby, Sweden.

Thellite. (*Chem. News*, 1870, XXI, 13, *thelline, thellite*). Damour's yttrium silicate from Brazil (Dana's *Min.* 6th Ed. p. 512).

Titanomagnetite. (P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 79.) Titaniferous magnetite. $[(Fe,Ti)O_3]_2Fe$.

Torrensite. H. Lienau, *Chem.-Zeit.* 1899, XXIII, 418. A compact reddish grey to sepia coloured mineral occurring with rhodonite at Torrens mine, Hautes-Pyrénées. $MnSiO_3.MnCO_3.\frac{1}{2}H_2O$.

Uranelain. R. Hermann, *Bull. Soc. Nat. Moscou*, 1832, V, 45; *Pogg. Ann.* 1833, XXVIII, 566. A transparent, yellow, gummy substance like rancid oil, containing C, H and O. So-called inflammable snow which fell in gov. Moscow in 1832.

Venturaite. See under Mayberyite.

Vestanite. (C. Hintze, *Handb. d. Min.* 1892, II, 832). The same as westanite.

Viellaurite. H. Lienau, *Chem.-Zeit.* 1899, XXIII, 418. A massive, dark grey mineral from near Vielle-Aure, Hautes-Pyrénées.
$5MnCO_3.2Mn_2SiO_4$.

Von Diestite. E. Cumenge, *Bull. Soc. franç. Min.* 1899, XXII, 25. Telluride of silver, bismuth, etc. Colorado.

Walaite. E. Bořický, *Lotos*, 1869, XIX, 19. The same as valaite.

Warrenite. See under Mayberyite.

Wickelkamazite. A. Brezina and E. Cohen, *Die Structur d. Meteoreisen*, Stuttgart, 1886; E. Cohen, *Meteoritenkunde*, 1894, p. 94. The kamacite surrounding accessory constituents in meteoric irons.

Xanthotitane. P. Groth, *Tab. Uebers. Min.* 3rd Ed. 1889, p. 156 *(Xanthotitan)*. The correct form of xanthitane.

Digitized by Google

Yttrium-apatite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 173. Apatite containing Y_2O_3 (3·36 per cent.), cerium, etc. South Greenland.

Ziegelite. (*Comm. Dir. Trab. Geol. Portugal*, 1898, III, 203.) The same as Ziegelerz = tile-ore (variety of cuprite).

Zinc-schefferite. J. E. Wolff, *Zeits. Kryst. Min.* 1900, XXXIII, 148. Schefferite containing some zinc. Franklin Furnace, New Jersey.

September, 1900.

Digitized by Google

NOTES AND COMMENTS.

WE regret to record the death, on June 26th, 1900, of Professor G. H. F. Ulrich, a contributor to this Magazine. Georg Heinrich Friedrich Ulrich was born on July 7th, 1830, at Zellerfeld in the Harz, and graduated at the School of Mines, Clausthal. In 1854 he emigrated to Victoria, and in 1858 was appointed Assistant Secretary to the Mining Commission at Melbourne; later he successively filled in the same colony the posts of Field Geologist of the Geological Survey, Curator of the Technological Museum, and Lecturer on Mining and Mineralogy in the University. From 1879 onwards, he was Professor of Mining and Mineralogy in the Otago University at Dunedin, New Zealand. His death was the result of a fall from a cliff while collecting rock specimens in the neighbourhood of Dunedin.

Professor Ulrich was the author of several reports and papers on mining and mineralogy, commencing in his early days with the minerals of the Harz. One of the most useful from a mineralogical point of view is his "Contributions to the Mineralogy of Victoria," published as a separate pamphlet in 1870, which is really a short treatise on the minerals of Victoria. The Victorian minerals maldonite, selwynite and talcosite were discovered and named by him.

We have received from the publisher, Thomas Murby, a new edition of Rutley's *Mineralogy* (the 12th) and of Skertchley's *Geology* (the 10th), two small but well known volumes belonging to Murby's Science and Art Department Series of Text-books. The *Mineralogy* has been increased by an outline of the modern treatment of Crystal Symmetry, and a table of the 32 classes similar to that in Penfield's *Determinative Mineralogy*. To the *Geology* has been added a section embracing the new requirements of the South Kensington Syllabus, viz. Rock-forming Minerals, Crystallography, Volcanic and Plutonic Rocks, and the Microscopical Examination of Rocks.

The following publications have been recently received:—

From the Agent-General for Victoria several of the Monthly Returns of the Gold Fields of Victoria. From the Greater Britain Exhibition at

Digitized by Google

Earl's Court, 1899, a Catalogue of the very complete exhibits, mainly of metalliferous ores, in the Queensland Court. Also a Guide to Queensland compiled by C. S. Rutlidge (Dean & Son), which gives a very full account of the resources of the Colony. From the Agent-General for Queensland several detailed Maps of Mining Districts prepared by the Government Geologists. From the Michigan College of Mines a Catalogue containing a full account of the courses of instruction provided in that institution. From the Editor the first number of a new weekly paper entitled *British Mining*.

Digitized by Google

REVIEW.

Notions de Minéralogie. Par A. F. Renard, Professeur à l'Université de l'État à Gand, et F. Stöber, Chargé de Cours à la même Université. Pp. x. and 374, avec 782 figures dans le texte. Gand, Ad. Hoste, 1900.

The present work is intended primarily for the use of students reading Mineralogy at the University of Ghent and in the affiliated engineering and other schools; but the authors have also kept in view the needs of others, such as chemists and geologists who may wish to gain a knowledge of the subject as an aid to their own special studies. It is divided into two sections, dealing respectively with the general and the systematic parts of the subject.

Part I (pp. 1-189) is devoted to the discussion of the geometrical and physical properties of crystals and the general and chemical characters of minerals. Among the points worthy of note in an elementary book are the adoption throughout of Millerian indices, to the exclusion of the symbols of Naumann, and the free use made of the stereographic projection. The main facts and relations of geometrical crystallography are clearly explained, and some examples are given of the method of "working out" a crystal by means of zones. Questions of calculation involving trigonometry are for the most part omitted.

The systems are discussed at some length, and the principal forms of the holosymmetric and of the more important merosymmetric types and their common combinations described and figured. It is perhaps a little unfortunate that the authors, while using planes of symmetry as the basis for the division into systems, make no reference to the other elements of symmetry, and in the subdivision into classes continue to give prominence to holohedral and merohedral characters, in many cases without considering the symmetry of which these are the outcome. A sketch given of the principles of twinning, and mimetic twinning is illustrated a description of phillipsite.

In view of its doubtful existence, the third type of twin-plane might perhaps have been better omitted. It may be noted also that wulfenite is not now grouped with scheelite as "pyramidal hemihedral," having no equatorial plane of symmetry (though the absence of this is not indicated in the figure given).

Digitized by Google

In the part allotted to physical crystallography, special prominence is given to the determination of optical characters, in view of their importance in petrographic work, and there is a useful paragraph on the interpretation of partially visible axial figures. Some elementary explanation of the formation of interference figures might with advantage have been added.

Four pages are devoted to a discussion of the ellipsoid of elasticity and the wave surface, but it may be open to doubt how far these will be intelligible to a student after the short acquaintance with the subject gained from the preceding pages.

The thermal, electric and magnetic properties of crystals are shortly treated, and there is a paragraph on optical anomalies.

A noticeable feature of the short section on chemical crystallography is the inclusion of a number of microchemical tests, with figures of the crystalline products. The use of etching figures in determining the symmetry of a crystal finds a place in this part, which concludes with an interesting chapter on the modes of formation of minerals in nature and in the laboratory.

The second division of the book (pp. 191-366) contains good descriptions of about 130 of the more important minerals, together with notes in smaller type on some of the rarer species, of which however a rather excessive number is admitted. The classification adopted is that of Groth's *Tabellarische Übersicht*. At the end is added a useful list of the minerals found in Belgium, with their principal occurrences; the materials of this list have not been previously collected together.

The illustrations are numerous, but the lettering of them is not always very legible. Several printer's errors (especially in indices) will be found which have escaped inclusion in the list of errata.

As a whole, the book forms a useful introduction to the subject of which it treats.

H. L. B.

Digitized by Google

INDEX TO VOL. XII.

(See also "List of New Mineral Names," p. 378.)

Abyssinia, rocks, 92, 255.
Ægirine-augite, Little I. of Trinidad, 319.
Ægirine rocks, Abyssinia, 255.
"Æschynite" of Hitterö, 99.
Africa, soda-rich igneous rocks, 273.
Albite, Tintagel, 360.
Allen (E. T.).—Native iron in coal measures, 46.
Alunite-quartz rock, 134.
Analcite, Barrhead, 130.
——— constitution, 312.
——— dehydration, 131.
——— optical anomalies. 51.
Anatase, Tintagel, 362.
Anorthite, cryst. 181, opt. 309.
Anorthoclase rocks, Abyssinia, 255.
Antarctic rocks, 69.
Apatite, blue, Ceylon, ix.
Apophyllite, S. Africa, 130.
Aragonite, cryst. 218, 219.
——— group, 218.
——— absence of in animal kingdom, 368.
Argyrodite, stanniferous, Bolivia, 5.
Arsenates and phosphates, 120, 152, 223, 234.
Arzruni (A.).—Obituary of, 129.
——— and Thaddéeff (K.).—New minerals, 307.
Arzrunite, 308.
Atacamite, Chili, cryst. opt. 15.
Augelite, Bolivia, 1.
Axial representation, Grassmann's method, 333.
Axinite, Cornwall, 281.

Bäckström (H.).—Phenakite, 134.
Baddeleyite, Sweden, 215.
Barium chloride, dehydration of, 312.
Barlow (W.).—New method of deriving the 32 crystal classes, xvi.
Barytes, cryst. 220.
——— in igneous rock, 49.
——— Bolivia, 4.
——— Hungary, 53.
——— Sardinia, 217.
Basalt, Abyssinia, 271.
——— Antarctic, 71–91.
——— -glass, Antarctic, 88.
Baumhauer (H.).—Anomalous etched figures; colemanite, 135.
Beckenkamp (J.). — Symmetry of crystals, 218.
Beudantite, composition, 234, 251.
——— cryst. opt. 242.
——— group, 249.
Binnenthal minerals, 285.
Binnite = tennantite, 184, 282.
Bismuth basic carbonate, Chili, 309.
Blende with metallic lustre, 111.
Blomstrand (C. W.).—Death of, 35.
Blowpipe analysis, 153.
Bolivia, 1, 5, 13, 46, 58.
Bonney (T. G.). – Parent-rock of diamond in S. Africa, 310.
Bornite, Tyrol, 135.
Boulangerite, Sweden, 48.
Bowman (H. L.).—Rhombic pyroxene, S. Africa, 349.
——— Thermal conductivity in crystals, 353.
——— Twin crystal of sapphire, 355.
——— Monazite, etc., Tintagel, 358.
Brauns (R.).—Fuchs' Anleitung zum Bestimmen der Mineralien, 43.

Digitized by Google

Brazil, 30, 244.
British minerals, 45, 92, 111, 120, 130, 152, 192, 215, 227, 237, 239, 242, 274, 324, 353, 358.
Brochantite, Chili, 309.
Brögger (W. C.).—Mossite and skogbölite, 130.
Broken Hill (N.S.W.), ii, 47.
Brongniardite (so-called crystallised) = argyrodite, 11.
Brush (G. J.).—Determinative Mineralogy, 126.

Cadell (H. M.).—Vivianite, 130.
Calcite, colouring matter of, 48.
——— cryst. 219.
——— Tintagel, 361.
——— etc. in animal kingdom, 369.
Calcium carbonate, new form of, 363.
——————— amorphous, 369.
——————— in animal kingdom, 363.
Caldbeck mines, 240, 227.
Canfieldite, 5.
Caracolite, 19.
Cassiterite, Swaziland, 100.
Cerium, valency of, 248.
Cerussite, Tuscany, 54.
Chalcophyllite, composition, 120.
Chalyphite, 135.
Chert, Antarctic, 73.
Chester (A. H.).—Krennerite, 132.
Chili, 15, 307.
Church (A. H.).—Experiments with zeolites, ix.
——————— Blue apatite, Ceylon, ix.
Clarke (F. W.).—Formula of tourmaline, 310.
——————— and Steiger (G.).—Constitution of silicates, 311.
Cliftonite, 171.
Clinohedrite, 133.
Cohen (E.).—Cohenite, 135.
Cohenite, in telluric iron, 135.
manite, etching, 135.
ng matter in calcite, 48.
363.
Copper-pyrites, Cornwall, cryst., 324.
——————— alteration of, 376.
Copper sulphate, dehydration of, 312.
Cordierite, formation in magmas, 314.
Corundum, artificial, 314.
——————— formation in magmas, 314, 148.
——————— N. Carolina, 139, 150.
——————— twin crystal, 355.
Crystal angles, table of, 43.
——— structure, 218, 305.
——— symmetry, 218.
Crystallography, treatises, 123, 214, 302.
Crystals in blowpipe beads, 153.
Cubic tetartohedrism in minerals, 51, 112.
Currie (J.).—Minerals from Mull, 130.
——————— Apophyllite, 130.
Cusack (R.).—Melting points of minerals, 49.

D'Achiardi (G.).—Optical anomalies of analcite, 51.
——————— Tuscan minerals, 53.
Dana (E. S.).—Text-book of Mineralogy and Crystallography, 123.
——————— Appendix to System of Mineralogy, 303.
Dannenberg (A.).—New minerals, 307.
Daviesite, 308.
Dehydration of minerals, 131, 312.
Des Cloizeaux (A. O.).—Obituary of, 37.
Diamond, artificial, 54.
——————— parent-rock in S. Africa, 310.
Dick (A.).—Crystals of lead, 118.
Dolerite, Abyssinia, 271.
——————— Antarctic, 83.
Domingite, 58.
Double-plate, quartz, 52.
Dufrenoysite, 286, 288.

Electrical phenomena, 218.
Embrithite, 49.
Enstatite, S. Africa, 349.
Epidiorite, Antarctic, 82.

Digitized by Google

Epsomite, Tuscany, 53.
Etch-figures, 21, 218, 357.
——— anomalous, 135.
Euxenite, Swaziland, 96.
Evans (J. W.).—Alteration of pyrites, 371.

Fahlerz, composition, 193.
Faroelite, 29.
Farrington (O. C.).—Average sp. gr. of meteorites, 50.
Feather-ore, 2, 58.
Felspar-basalt, Antarctic, 71.
Fergusonite (?), Swaziland, 100.
Fiedlerite, cryst. opt. 107.
Fletcher (L.). — Meteoric iron from Caperr, Patagonia, 167.
——— Cliftonite and tænite in Youndegin iron, 171.
Fletcher (T.).—Coal gas, 36.
Florence (W.).—Crystals in blowpipe beads, 153.
Florencite, 244, 249.
Flos ferri, 369.
Foote (H. W.) and Penfield (S. L.).—Clinohedrite, 133.

Formula of tourmaline, 216, 309.
Foote (W. M.).—Native lead, 315.
Franklin Furnace (N. J.), 133, 315.
Friedel (G.).—Dehydration of analcite, 131.
Fromme (J.).—Colouring matter of calcite, 48.
Fuchs (C. W. C.).—Anleitung zum Bestimmen der Mineralien, 43.

Galena, zinciferous, Utah, 112.
Garnet (rhodolite), 145, 133.
——— (soda-), 314.
Geinitz (H. B.).—Obituary of, 300.
Geocronite, 290.
Germanium, detection of, 9.
Glaucochroite, 316.
Glauconitic sandstone, Antarctic, 90.
Gneiss, Antarctic, 91.
Gold nuggets, crystalline structure, 135.
Goldschmidt (V.). — Krystallographische Winkeltabellen, 43.
Goniometer, theodolite-, 52, 114, 176.
——— three-circle, 175.
Goodchild (J. G.). - Obituary of M. F. Heddle, 38.
——— Minerals from Hilderston silver mines, 130.
Granite, Antarctic, 77, 82, 89.
Grassmann's method of axial representation, 333.
Gregory (J. R.). - Obituary of, 301.
Grorudite, Abyssinia, 255.
Groth (P.).—Tabell. Uebers d. Mineralien, 36.
Grünlingite, 45.
Gypsum, conduction of heat in, 353.
——— cryst., 219.
——— weathering figures, 137, 354.
——— Bolivia, 2.

Hall (A. L.) and Lewis (W. J.).—Crystals of copper-pyrites, Cornwall, 324.
Hamlinite, composition, 45.
——— group, 249.
Hancockite, 316.
Hardness of minerals, 50.
Hardystonite, 315.
Hartley (E. G. J.).—Constitution of mineral arsenates and phosphates:
I. Chalcophyllite, 120.
II. Pharmacosiderite, 152.
III. Plumbogummite and hitchcockite, 223.
IV. Beudantite, 234.
——— analysis by, 111.
Hartley (W. N.) and Ramage (H.).—Spectrographic analysis of meteorites, 50.
Heat, curve of conductivity in crystals, 353.
Heavy liquid for separating minerals, 131.
Heddle (M. F.).—Analcite, 130.
——— Riebeckite, 130.
——— Mineralogy of Scotland, v, 215.

Digitized by Google

Heddle (M. F.).— Obituary of, 38.
Heimerl (A.).—Bornite, 135.
Hemimorphite, constitution, 312.
Heteromorphite, 57.
Heulandite, optical characters and loss of water, 313.
Hidden (W. E.) and Judd (J. W.).—Ruby in N. Carolina, 139.
——— and Pratt (J. H.).—Rhodolite, 133.
Hintze (C.). — Handbuch der Mineralogie, 36.
——— Phenakite, 134.
Hitchcockite, composition, 223, 250.
——— Cumberland, 227, 239.
——— Georgia, 228, 241.
Hlawatsch (C.).—Stolzite and raspite, 47.
Holland (T. H.).—Quartz-barytes rock, 49.
Hudson (R. W. H. T.).—Determination of position of points and planes after rotation about a known axis, 343.
Hussak (E.). — Baddeleyite, Sweden, 215.
——— and Prior (G. T.).—Senaite, a new mineral, 30.
——— Florencite, a new mineral, 244.
Hutchinson (A.).—Stokesite, a new mineral, 274.
——— Optical properties of chalybite and dialogite, xvii.
——— Obituary of C. F. Rammelsberg, 298.

I'Anson (J.).—Death of, 35.
Ilmenite group, 30.
Iron, native, in coal measures of Missouri, 46.
—— telluric, cohenite in, 135.
Isomorphism, theory of, 305.
——— mass effect, 217, 203, 253.

Jackson (H.).—Analyses by, 282.
Jagger (T. A. Junr.).—Microsclerometer for determining hardness, 50.
Jamesonite, 58.
Japan, minerals, 313.
Jimbō (K.).—Minerals of Japan, 313.
John (C. von).—Moldavite, 311.
Jordanite, composition, 288.
——— cryst. 290.
Judd (J. W.) and Hidden (W. E.).—Ruby in N. Carolina, 139.

Kelley (J. G.). — Boy Mineral Collectors, 128.
Kelly (A.).—Conchite, a new form of calcium carbonate, 363.
Klein (C.).—Leucite and analcite, 51.
——— Bornite, 135.
——— Optical studies, 309.
Krennerite, Colorado, 132.
Kyschtymite, 314.

Lacroix (A.).—Modification of granitic magma by limestone, 136.
Lagoriolite, 314.
Langbeinite, Prussia, 51.
——— India, 159.
Laurionite, cryst. opt. 102.
Lead crystals, 113, 118.
Leonard (J. W.).—Gold Fields of Klondike, 36.
Leucite, optical anomalies, 51.
Leucophœnicite, 316.
Lewis (W. J.).—Grassmann's method of axial representation, 333.
——— Treatise on crystallography, 302.
——— and Hall (A. L.). — Crystals of copper-pyrites, Cornwall, 324.
Limburgite, Little I. of Trinidad, 322.
Limestone, Antarctic, 74.
Lindgren (W.).—Orthoclase in mineral veins, 133.
Lindöite, Abyssinia, 261, 262.
Liversidge (A.).—Crystalline structure of gold nuggets, 135.
Luedecke (O.).—Langbeinite, 51.

Machacamarca, Bolivia, 3.
Madagascar, rocks, 272.

Digitized by Google

Magma, granitic, modified by limestone, 136.
Magmas, formation of minerals in, 313.
Majorana (Q.).—Artificial diamond, 54.
Mallet (F. R.).—Langbeinite, Punjab, 159.
Marcasite, alteration of, 376.
Marsh (C. W.).—Stolzite, 47.
Matildite, Japan, 313.
Melanotekite, New Mexico, 134.
Meldometer, 49.
Melting points of minerals, 49.
Meneghinite, 290.
Merohedrism, theory of, 306.
Mesole, 29.
Meteoric iron, Caperr, Patagonia, 167.
——— Youndegin, 171.
Meteoric origin of moldavite, 311.
Meteorites, average sp. gr. 50.
——— gallium, etc., in, 50.
——— spectrographic analysis, 50.
Miargyrite, Bolivia, 12.
Microsclerometer, 50.
Miers (H. A.).—Blende, galena, pyrites, lead, 111.
——— Hitchcockite, plumbogummite, beudantite, 239.
——— Obituary of A. O. Des Cloizeaux, 37.
——— A. Schrauf, 42.
Miltosevich (F.).—Sulphur, etc., Sardinia, 217.
Mineral analyses, reliability of, 249.
Mineralogy, determinative, 43, 126.
——— Treatises, 36, 123, 303, 395, 397.
Minerals, action of water on, 375.
——— British, *see* British.
——— formation of in magmas, 313.
——— hardness, 50.
——— melting points, 49.
——— new names, 378.
——— heavy liquid for separating, 131.
Mispickel, constitution, 182.
Moldavite, cosmic origin of, 311.
Monazite, Cornwall, 358.
——— Swaziland, 101.
Morozewicz (J.). — Formation of minerals in magmas, 313.
Morphotropic series, 66.
Moses (A. J.).—Characters of Crystals, 214.
Mossite, 130.
Muthmann (W.).—Heavy liquid for separating minerals, 131.
——— and Schröder (E.).—Grünlingite, 45.

Nasonite, 316.
Nepheline-basanite (?), Antarctic, 91.
Nepheline rocks, Little I. of Trinidad, 318.
Niobates, Swaziland, 96.
North Carolina, 139, 133.
Nosean rocks, Little I. of Trinidad, 320.

Obituary, Arzruni, A., 129.
——— Blomstrand, C. W., 35.
——— Des Cloizeaux, A. O., 37.
——— Geinitz, H. B., 300.
——— Gregory, J. R., 301.
——— Heddle, M. F., 38.
——— I'Anson, J., 35.
——— Rammelsberg, C. F., 298.
——— Sandberger, K. L. F. von, 35.
——— Schrauf, A., 42.
——— Ulrich, G. H. F., 395.
Opal, precious, New Zealand, 34.
Optical anomalies, 51, 305.
——— determinations, 52, *see* refractive indices.
——— indicatrix, 124.
Orthoclase in mineral veins, 133.
Oxford Mineralogical Laboratory, 111, 120, 152, 223-239, 349.

Paisanite, Abyssinia, 95, 263.
Palagonite-tuff, Antarctic, 77, 86, 89.
Paralaurionite, 108, 183.
Pectolite, constitution, 311.
Penfield (S. L.).—Hamlinite, 45.
——— New edition of Brush's Determinative Mineralogy, 126.

Digitized by Google

Penfield (S. L.) and Foote (H. W.).—Clinohedrite, 133.
———— Formula of tourmaline, 216, 309.
———— and Warren (C. H.).—New minerals, 315.
Pharmacosiderite, composition, 152.
Phenakite, new localities, 134.
Phillipsite, ix.
Phonolite, Antarctic, 78.
———— Little I. of Trinidad, 318.
———— -nephelinite, Little I. of Trinidad, 321.
Phosgenite, Laurium, 107.
Picromerite, Punjab, 166.
Pirsson (L. V.).—36.
Pitchstone, Abyssinia, 270.
Plagionite, 56.
Platinum nuggets, crystalline structure, 135.
Plumbogummite, 223, 241, 250.
Plumosite, 58.
Polymorphism, theory of, 305.
Pratt (J. H.).—Crystallography of ruby, N. Carolina, 150.
———— and Hidden (W. E.)—Rhodolite, 133.
Prior (G. T.).—Sphærostilbite, 26.
———— Antarctic rocks, 69.
———— Riebeckite in trachytic rocks from Abyssinia, 92.
———— Minerals from Swaziland: the "æschynite" of Hitterö, 96.
———— Hamlinite, florencite, plumbogummite, beudantite, svanbergite group, 249.
———— Ægirine and riebeckite anorthoclase rocks, Abyssinia, 255.
———— Rocks from Little I. of Trinidad, 317.
———— Analyses by, 55, 102.
———— and Hussak (E.).—Senaite, a new mineral, 30.
———— Florencite, a new mineral, 244.
———— and Spencer (L. J.).—Stanniferous argyrodite from Bolivia; Identity of "crystallised brongniardite" with argyrodite-canfieldite, 5.
Prior (G. T.) and Spencer (L. J.).—Identity of binnite with tennantite: composition of fahlerz, 184.
Pseudomorphs, 33, 239.
———— after pyrites, 372.
Punjab Salt Range, 165.
Pyrargyrite, Bolivia, 6.
Pyrites, alteration of, 371.
———— tetartohedral (?), Colorado, 112.
———— Bolivia, 2.
———— Tintagel, 361.
———— Tuscany, 54.
Pyromorphite, aluminous, 233.
Pyrophyllite, constitution, 311.
Pyroxene, rhombic, S. Africa, 349.

Quartz, Japan, 313.
———— Tintagel, 360.
———— double-plate, 52.
———— pseudomorphs, 33.
———— -alunite rock, 134.
———— -barytes rock, 49.
———— -grit, Antarctic, 85.

Rafaelite = paralaurionite, 183, 308.
Ramage (H.) and Hartley (W. N.).—Spectrographic analysis of meteorites, 50.
Rammelsberg (C. F.).—Obituary of, 298.
Raspite, 47.
Rathite, composition, 287.
Refractive indices, determination, 22, 105, 309.
Renard (A. F.) and Stöber (F.).—Notions de Minéralogie, 397.
Rheineck (H.).—Formula of tourmaline, 310.
Rhodolite, 133, 145.
Rhombohedral system, 338.
Rhyolite, Antarctic, 85, 90.
Riebeckite, Abyssinia, 92, 255.
———— Ailsa Craig, 130.
Rinne (F.).—Water of crystallisation, 312.
Rocks, Abyssinia, 92, 255.
———— (soda-rich) Africa, 271.
———— Antarctic, 69.

Digitized by Google

Rocks, Little I. of Trinidad, 317.
——— corundum-bearing, N. Carolina, 139.
——————— Urals, 314.
Ross (Sir J. C.).—Antarctic Expedition (1839–43), 69, 317.
Rotary polarisation, 221.
Rotation about axis, positions of points and planes after, 343, 330.
Roughten Gill mines, 240, 227.
Ruby, North Carolina, 139, 150.
Rutile, Cornwall, 360.
Rutley (F.) Mineralogy, 395.

Sandberger (K. L. F. von).—Obituary of, 35.
Sapphire, twin crystal, 355.
Saprolite, 142.
Sartorite, chem. 286, cryst. 297.
Schists, Antarctic, 85.
Schmidt (A.).—Minerals from Hungary, 53.
Schrauf (A.).—Obituary of, 42.
Schröder (E.) and Muthmann (W.).—Grünlingite, 45.
Schroeder van der Kolk (J. L. C.).—36.
Scolecite, Mull, 130.
Semseyite, Harz, 60.
Senaite, 30.
Shells, molluscan, etc., 363.
Shock (H. L.). *See* Starke (F. W.).
Silicates, constitution, 311.
Sillimanite, formation in magmas, 314.
Sjögren (H.).—Boulangerite, 48.
Skertchley's Geology, 395.
Skogbölite = tapiolite, 131.
Smith (E. F.). *See* Starke (F. W.),
Smith (G. F. H.).—Atacamite, Chili, 15.
——————— Lead minerals from Laurium; laurionite, phosgenite, fiedlerite, and (new species) paralaurionite, 102.
——————— Three-circle goniometer, 175.
——— ——— ——— Identity of paralaurionite and rafaelite, 183.
Sohncke (L.).—"Weathering figures" of gypsum, 137.
Solly (R. H.).—Sulpharsenites of lead, Binnenthal, 282.
Sölvsbergite, Abyssinia, 265.
Spectrographic analysis of meteorites, 50.
Spencer (L. J.).—Augelite, Bolivia, 1.
——————— Plagionite, heteromorphite and semseyite, 55.
——— ——— List of new mineral names, 378.
——————— Measurements by, 95, 101.
——————— and Prior (G. T.).—Stanniferous argyrodite from Bolivia; Identity of "crystallised brongniardite" with argyrodite-canfieldite, 5.

Identity of binnite with tennantite; composition of fahlerz, 184.
Sphærostilbite = thomsonite, 26.
Spinel, artificial, 314.
——— formation in magmas, 314.
Stannite, Bolivia, cryst. 46. xv.
Starke (F. W.), Shock (H. L.) and Smith (E. F.).—Constitution of mispickel, 132.
Stauroscopic measurements, 52.
Steiger (G.) and Clarke (F. W.).—Constitution of Silicates, 311.
Stelzner (A. W.).—Crystallised stannite, Bolivia, 46.
Stelznerite, 308.
Stephanite, Bolivia, 6.
Stibnite, conduction of heat in, 355.
——— Hungary, 53.
Stilbite, radiating, 29.
——— dehydration of, 312.
Stöber (F.).—Quartz double-plate, 52.
——— —— Theodolite-goniometer, 52.
——————— and Renard (A. F.). — Notions de Minéralogie, 397.
Stokesite, 274.
Stolzite, N.S. Wales, 47.
Strontianite, cryst. 218.
Suess (F. E.),—Cosmic origin of moldavite, 311.
Sulpharsenites of lead, 282.
Sulphostannates in Bolivia, 13, 46.

Digitized by Google

Sulphur, Sardinia, 217.
Svanbergite, composition, 252.
Swaziland, 96.

Tænite in Youndegin iron, 172.
Tammela tantalite, 131.
Tapiolite, Finland, Maine, 131.
Tennantite, Binnenthal, 184.
———— Cornwall, 192.
———— composition, 193.
Termier (P.).—Zoisite, 215.
Tetradymite, Hungary, 46.
Tetrahedrite, Baden, 200.
———— Dauphiné, 196.
———— Horhausen, 198.
———— composition, 193.
Thaddéeff (K.) and Arzruni (A.).—New minerals, 307.
Theodolite-goniometer, 52, 114, 176.
Thermal conductivity in crystals, 353.
Thomsonite ("sphærostilbite"), 26.
Three-circle goniometer, 175.
Tin silicate, 280.
Tinguaite, Abyssinia, 255.
Tintagel (Cornwall), 358.
Tourmaline, formula, 216, 309.
Trachyte, Abyssinia, 90, 270.
———— Madagascar, 272.
Trinidad, Little I. of, rocks, 317.
Tschermak (G.).—Formula of tourmaline, 310.
Turner (H. W.).—Quartz-alunite rock, 134.
Twin-crystals, 7, 108, 220, 327.
Twin-crystals, drawing, 330.
Twisted crystals, 68.

Ulrich (G. H. F.).—Quartz pseudomorphs, New Zealand, 33.
———— Obituary of, 395.
Utahite, Chili, 308.

Vicinal faces, 2, 219.
Vivianite, Linlithgow, 130.

Wallerant (F.).—Theory of optical anomalies, isomorphism and polymorphism, 305.
Warren (C. H.).—Tapiolite, 131.
———— Melanotekite, phenakite, 134.
———— and Penfield (S. L.).—New minerals, 315.
Warrenite, 58.
Water of crystallisation, 131, 312.
Watts (W. W.).—Geology for Beginners, 125.
Weathering figures of gypsum, 137, 354.
Weinschenk (E.).—Bornite, 135.
Wolff (J. E.).—Native copper, hardystonite, 315.

Zeitschrift f. Kryst. Min., Repertorium u. General Register, 304.
Zinc-blende, *see* Blende.
Zoisite, opt. 215.

Digitized by Google

ERRATA.

VOL. I.

PAGE	LINE	
66	5	*for* Kengott *read* Kenngott.
135	3	

VOL. IV.

v	11	*for* Terril *read* Terrill.

VOL. V.

ii	11	*for* Davis *read* Davies.

VOL. VII.

xii	9*	*for* Ulrichs *read* Ulrich.
237	14*	*for Reichsantalt read Reichsanstalt.*

VOL. VIII.

202	5* *(f. n.)*	*for Geologiska Foreningens de Stockholm*, 1887, *read Geologiska Föreningens i Stockholm Förhandlingar*, 1877.
215	6*	*for fur read für.*

VOL. IX.

10	1	*for* Pzibram *read* Przibram.

VOL. X.

148	5	*for* June 16th *read* June 14th.
220	1* *(f. n.)*	*for* 1877 *read* 1882.
226	7*	*for* 100 : *hhl read* 110 : *hhl.*
227	4*	*for* (13.$\overline{13}$.1) *read* (13.$\overline{13}$.2).
—	col. 5	*for* calculated : 100 *read* calculated : 110.

VOL. XI.

xxii	21	*for* Prof. Liveing, Mr. Mallet, Mr. Prior and Mr. Rutley *read* Messrs. Harker, Lewis, Tutton and Watts.

* From bottom of page.

Digitized by Google

VOL XI—*Continued.*

PAGE	LINE	
77	5* *(f. n.)*	*for* Stocker-Escher *read* Stockar-Escher.
300	16	*for* Sundtite *read* Andorite.
345	9–11	*dele.*
346	17	*for* interests *read* intervals.

VOL. XII.

i	16	*for* Brogniardite *read* Brongniardite.
viii	24	*for* M.A. *read* B.Sc.
3	1* *(f. n.)*	*for* $Bx_a \wedge c$ *read* $Bx_a \wedge c'$.
4	1* *(f. n.)*	*for* pp. 46, 7, *read* 46, 14.
11	24	*for* these *read* three.
17	6*	*for* 42°41′ *read* 41°41′.
		for 41°49′ *read* 40°49′.
17	3*	*for* 40°57′ *read* 49°57′.
19	1*	*for bs read es.*
—	8*	
—	8*	*for bm read em.*
21	18*	*for* 111 : $\bar{1}11$ *rr‴* *read* 111 : $1\bar{1}1$ *rr‴*.
22	8	*for* (132) *read* (341), *dele* " probably *k*."
—	9	*for* ($13\bar{2}$) *read* ($34\bar{1}$).
—	13	*for* 132 *read* 231.
—	14	*for* 231 *read* 341.
—	15	*dele.*
26	6	*for Mineralogy read Minéralogie.*
28	8*	*for* Flanders Island, Tasmania, *read* Flinders near Melbourne.
38	2–3	*for* discovery and definition *read* practical application.
—	21	*for* 1870 *read* 1878.
40	10*	*dele* " a new Edition of "
41	13	*for* Proceedings *read* Transactions.
47	8	*for* deltoid-dodecahedral *read* triakis-tetrahedral.
51	2*	*Insert* (see, however, Min. Mag. IX, 211).
52	1	*for* Zuckswerdt *read* Zuckschwerdt.
71–3	*(f. n.)*	*for Neues Jahrb. f. Min. u. Petr. read Neues Jahrb. f. Min. Geol. u. Pal.*
71	1* *(f. n.)*	*for* p. 179 *read* p. 79.
72	*(f. n.)*	*for* p. 224 *read* Ref. p. –224–.
109	3	*See* p. 183 *(f. n.).*
252	15*	*for* SO *read* SO_3.
301	3*	*dele* of the Geological Society.
303	21	*for* 1893 *read* 1892.

Nos. 53, 54, 55, 56, 57, p. 3 of cover, in list of honorary members add Dr. K. J. V. Steenstrup, Copenhagen.

No. 55, p. 2 of cover, line 11*, *for* M.A. *read* B.Sc.

* From bottom of page.

Digitized by Google

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, February 1st, 1898.

N. S. Maskelyne, Esq., F.R.S., President, in the Chair.

The death of Professor Heddle, Past President, was announced.

Professor Church was elected, by co-optation, to the office of Vice-President vacated through the death of the Rev. Prof. S. Haughton.

Mr. E. G. J. Hartley was elected an Ordinary Member of the Society.

The resignation of Dr. Robert Oxland, Original Member of the Society, was reported.

GENERAL MEETING.

Held in the Apartments of the Geological Society, February 1st, 1898.

N. S. Maskelyne, Esq., F.R.S., President, in the Chair.

Eighteen Members were present.

The following papers were read:—

1. Canfieldite from Bolivia: Specific identity of so-called "Crystallised Brogniardite" and Canfieldite: by Mr. G. T. Prior and Mr. L. J. Spencer.

2. On Atacamite from Sierra Gorda, Atacama: by Mr. G. F. H. Smith.

Mr. Bowman showed specimens of stibnite in which the differences of conductivity for heat in different directions were proved by the volatilisation of a thin layer of ammonium chloride from the neighbourhood of a heated point, and specimens of gypsum from which the water had been driven off in the vicinity of a heated point.

Mr. Prior showed some balls of oolitic limestone from Turk's Island, Bahamas, and Mr. Hutchinson an enlarged photograph of the late Professor Miller, of Cambridge.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, April 5th, 1898.

Dr. Hugo Müller, F.R.S., Vice-President, in the Chair.

The resignation of Mr. John Gill was accepted.

The audited Balance Sheet for the year ending Dec. 31st, 1897, was

Digitized by Google

submitted and approved: the Secretary was instructed to insert it in the Minutes as usual, and to issue a printed copy with the next number of the Journal.

GENERAL MEETING.

Held in the Apartments of the Geological Society, April 5th, 1898.

Dr. Hugo Müller, F.R.S., Vice-President, in the Chair.

Eleven Members were present.

The following papers were read:—

1. Sphærostilbite: by Mr. G. T. Prior.

2. On the occurrence of Monazite, and niobates and tantalates of the rare earths, in Swaziland: by Mr. G. T. Prior.

3. On a cubic modification of silver iodide from Broken Hill, New South Wales: by Mr. L. J. Spencer.

4. On peculiar quartz-pseudomorphs found at the Owera Mine, Opitonui, New Zealand: by Prof. G. H. F. Ulrich (communicated by Professor Judd).

5. Crystallographic notes on Laurionite and Phosgenite: by Mr. Herbert Smith.

6. On Senaite, a titanate of iron, lead and manganese, from Brazil: by Dr. E. Hussak and Mr. G. T. Prior.

Specimens were shown illustrative of the Senaite (by Mr. Prior), the silver iodide (by Mr. Spencer), and of the quartz pseudomorphs from New Zealand for Prof. Ulrich.

Digitized by Google

Mineralogical Society—Abstract of Receipts and Payments from 1st January to 31st December, 1897.

RECEIPTS.

	£ s. d.	£ s. d.
Balance from year 1896		49 18 0
Subscriptions:—		
(1) In advance	1 1 0	
(2) Current	43 0 10	
(3) In arrear	10 10 0	
		54 11 10
Entrance Fees and Compositions		48 6 0
Sale of Publications:		
(1) From Publishers	25 7 0	
(2) In Office	3 14 0	
		29 1 0
Authors' Extra Copies of Papers		5 9 9
Prof. O'Reilly for Illustrations		11 7 0
Dividends on Stock		9 6 3
		£207 19 10

PAYMENTS.

	£ s. d.	£ s. d.
Printing and Stationery		30 0 10
Illustrations		17 12 6
Purchase of Serials for Library		0 13 0
Binding Books for ditto		19 0 9
Clerical Expenses, *re* Removal and Care of Stock		2 2 0
Attendants' Fees at Meetings		1 1 0
Commission on Cheques		0 3 0
Investments and Brokers' Commission		59 6 3
Balance at Bank	£77 18 2	
,, in Office	0 2 4	
		78 0 6
		£207 19 10

Examined and compared with the vouchers and found correct. (Signed)

February 16th, 1898.

BENEDICT KITTO, } *Auditors.*
J. H. COLLINS, }

LIABILITIES.

	£ s. d.
Printers' Account	46 12 9
Secretarial Postage for 1897	1 4 1
Excess of Assets over Liabilities	521 2 1
	£568 19 9

The number of Life Members on December 31st, 1897, was 44.

ASSETS.

	£ s. d.
Balance as above	78 0 6
Subscriptions unpaid	20 0 0
Stock in 2¾ Consols: £339 6s. 7d. at 112	447 8 7
Dividend on Stock, January 1898	2 13 2
Sale of Journals, due from Publisher	11 7 6
Due for Authors' Copies	9 10 0
	£568 19 9

MEMO.—The Stock and Publications and the Library are not included in the above assets.

(Signed) F. W. RUDLER,
Treasurer.

Digitized by Google

Digitized by Google

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 21st, 1898.

Prof. A. H. Church, M.A., F.R.S., Vice-President, in the Chair.

The death of Professor Sandberger, Honorary Member, was announced.

A letter from Mr. Thoms, relative to the proposed publication of Prof. Heddle's *Mineralogy of Scotland*, was read.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 21st, 1898.

Prof. A. H. Church, M.A., F.R.S., Vice-President, in the Chair.

Thirteen Members and two Visitors were present.

The following papers were read:—

1. On some crystal forms of Lead: a study in crystal measurement: by Professor Miers (page 113).

2. On the chemical composition of Chalcophyllite: by Mr. E. G. J. Hartley (page 120).

3. On a possibly dimorphous form of an oxy-chloride of lead: by Mr. Herbert Smith (page 108).

Mr. Tutton exhibited an improved form of interference-dilatometer, and demonstrated the mode of use.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, October 4th, 1898.

Professor N. S. Maskelyne, M.A., F.R.S., President, in the Chair.

A proposal for an exchange of publications with the Imperial University of Moscow was accepted.

Resolved to nominate for the new Council as follows:—

President: Prof. Church (in succession to Prof. Maskelyne).

Vice-President: Prof. Liveing (in succession to Prof. Church). Messrs. Cole, Gurney, Platnauer, Teall, Tutton and Watts (in succession to Messrs. Church, J. Geikie, Hutchinson, Kitto, Liveing and Rutley), as Members of Council.

Digitized by Google

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 15th, 1898.

Prof. N. S. Maskelyne, M.A., F.R.S., President, in the Chair.

MM. Fouqué and Lévy were elected Corresponding Members of the Society.

Mr. J. P. de Castro, B.A., and Mr. H. C. Dickson were elected Ordinary Members of the Society.

The Draft Annual Report prepared by the Secretary was emended and approved.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 15th, 1898.

Prof. N. S. Maskelyne, M.A., F.R.S., President, in the Chair.

Eighteen Members were present.

The following Report of Council for the Session 1897-8 was read:—

REPORT.

The Balance Sheet for the year ending December 31st, 1897, which was issued with Number 54 of the Journal, showed that the state of the Finances of the Society was all that could be wished, the Assets (exclusive of the Stock of the Journal and the Library) amounting to £568 19s. 9d., and the Liabilities to £47 16s. 10d. The number of actual Members who had compounded before December 31st, 1897, for the payment of their Annual Subscription was 44.

During the Session 1897-8 two Members have been removed by death, namely, Professor Heddle, Past-President, and Professor Sandberger, Corresponding Member; one Member has resigned; five non-effective Members have been removed for non payment of their Subscriptions: on the other hand, two Corresponding Members and three Ordinary Members have been elected to the Society.

The total number of Members is now 131: of these 110 are Ordinary Members and 21 are Corresponding Members.

Four Meetings have been held during the year, all in London, (by kind permission) in the Apartments of the Geological

Digitized by Google

Society, Burlington House. The attendances at these Meetings have been 15, 18, 11 and 15, respectively.

Two Numbers of the Journal, published in December 1897 and June 1898, respectively, have been issued since the last Anniversary Meeting. To Number 53 Professor Miers contributed detailed information relative to British Pseudomorphs, information which it is very useful to place on record. Messrs. Prior and Spencer gave an elaborate report of their investigations relative to the species Andorite, Sundtite and Webnerite, and established their identity. Dr. Hussak, who is adding so much to our knowledge of the Mineralogy of Brazil, described, in conjunction with Mr. Prior, a new species, an antimonate of iron, Tripuhyite. Mr. Derby, also working in Brazil, announced the common occurrence of Monazite and Xenotime in the far-distant European rocks. Mr. Mallet gave the results of a minute chemical and optical examination of crystals of Blödite, and Mr. Henderson described a new mode of occurrence of Apophyllite in South Africa. A very noteworthy addition to the Number is Mr. Spencer's alphabetical list of the Mineral Species which have been named since the issue of the last edition (1892) of Dana's *System of Mineralogy*. An elaborate Index, compiled by Mr. Spencer, brings Volume XI. to a conclusion.

Number 54 contains information from Mr. Spencer about Augelite from a new locality in Bolivia. The same author, collaborating with Mr. Prior, proves that the mineral, long supposed to be a crystallised form of Brongniardite, is really a stanniferous Argyrodite. Mr. Herbert Smith, in a paper which we may hope to be followed by many others, contributes to our knowledge of Atacamite. Dr. Hussak describes a new mineral from Brazil, Senaite, belonging to the Ilmenite group, the analysis being by Mr. Prior, who in a subsequent paper critically discusses the existence of the species named Sphærostilbite. For the Abstracts which appear in the two Numbers the Society is indebted to the patient industry of Mr. Spencer and Mr. Herbert Smith.

The Council has to congratulate the Society on the continued steady sale of the Journal.

The Report of the Council was adopted.

Digitized by Google

The Elections of MM. Fouqué and Lévy as Corresponding Members and of Messrs. De Castro and Dickson as Ordinary Members were announced.

Messrs. Barlow and Hutchinson, having been nominated by the President to act as scrutators of the voting-papers for the election of Officers and Council, reported that 59 ballot-papers had been returned, and that the Officers and Council nominated have been elected, namely :—

President.	Prof. A. H. Church, M.A., F.R.S.
Vice-Presidents.	Prof. G. D. Liveing, M.A., F.R.S.
	Mr. Hugo Müller, Ph.D., F.R.S.
Treasurer.	Mr. F. W. Rudler, F.G.S.
General Secretary.	Mr. L. Fletcher, M.A., F.R.S.
Foreign Secretary.	Prof. J. W. Judd, C.B., F.R.S.
Twelve Ordinary Members of Council.	Mr. W. Barlow, F.G.S., F.C.S.
	Prof. Grenville A. J. Cole, M.R.I.A., F.G.S.
	The Rev. H. P. Gurney, D.C.L., M.A., F.G.S.
	Mr. F. R. Mallet, F.G.S.
	Lieut.-Gen. C. A. McMahon. F.R.S.
	Prof. H. A. Miers, M.A., F.R.S.
	Mr. H. M. Platnauer, B.Sc., A.R.S.M., F.G.S.
	Mr. W. J. Pope, F.C.S.
	Mr. G. T. Prior, M.A., F.G.S.
	Mr. J. J. H. Teall, M.A., F.R.S.
	Mr. A. E. Tutton, M.A., A.R.C.S., F.C.S.
	Prof. W. W. Watts, M.A., F.G.S.

A vote of thanks to the Auditors, Mr. J. H. Collins and Mr. B. Kitto, was passed, and the Auditors were re-elected.

A vote of thanks to the retiring Officers and Council was proposed by Professor Miers and seconded by Dr. Müller, and was carried with acclamation. The retiring President, Professor Maskelyne, expressed his gratification at the way in which the motion had been received.

A vote of thanks to the Geological Society for the use of its Apartments was carried.

The following papers were read :—

1. Plagionite, Heteromorphite and Semseyite as Members of a Natural Group of Minerals: by Mr. L. J. Spencer: with chemical analyses by Mr. G. T. Prior (page 55).

2. Petrographical Notes on rock-specimens collected during the Ross Antarctic Expedition of 1839-43: by Mr. G. T. Prior (page 69).

3. Mineralogical Notes from the Oxford University Laboratory: communicated by Prof. H. A. Miers (page 111).

Digitized by Google

4. Note on the occurrence of Riebeckite in trachytic rocks from Abyssinia: by Mr. G. T. Prior (page 92).

5. Mineral Deposits of the Binnenthal: by Mr. R. H. Solly.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, January 31st, 1899.

Prof. A. H. Church, M.A., F.R.S., President, in the Chair.

Mr. J. Currie, M.A., F.R.S.E., and Mr. C. G. Cullis, B.Sc., were elected Ordinary Members of the Society.

The resignation of Mr. T. Warburton was announced.

The Auditors' Balance Sheet for the year ending December 31st, 1898, was submitted and approved.

GENERAL MEETING.

Held in the Apartments of the Geological Society, January 31st, 1899.

Prof. A. H. Church, M.A., F.R.S., President, in the Chair.

Twenty-one Members and four Visitors were present.

The following papers were read:—

1. On a new mode of occurrence of Ruby, in North Carolina: by Prof. J. W. Judd, C.B., LL.D., F.R.S., and Mr. W. E. Hidden, F.G.S.; with crystallographic notes by Dr. J. H. Pratt.

2. Experiments with Zeolites: by Prof. A. H. Church, F.R.S., President.

3. Analyses of Ceylon Apatite: by Prof. A. H. Church, F.R.S., President.

4. On the constitution of the Mineral Arsenates and Phosphates. II. Pharmacosiderite: by Mr. E. G. J. Hartley.

5. On the specific identity of Binnite and Tennantite: by Mr. G. T. Prior and Mr. L. J. Spencer.

Prof. Church exhibited blue Apatites from Ceylon, one containing as much as 8·21 per cent. of chlorine, others only 0·68 and 0·84 per cent. He stated that the action of silver nitrate on Phillipsite is analogous to that investigated by Eichhorn and Lemberg in the case of salts on other zeolites.

Digitized by Google

Mineralogical Society—Abstract of Receipts and Payments from 1st January to 31st December, 1898.

RECEIPTS.

	£ s. d.	£ s. d.
Balance from year 1897		78 0 6
Subscriptions:—		
(1) In advance	1 1 0	
(2) Current	40 18 10	
(3) In arrear	29 8 0	
		71 7 10
Entrance Fees and Compositions		23 2 0
Sale of Publications:—		
(1) From Publishers	11 7 6	
(2) In Office	9 9 11	
		20 17 5
Dividends on Stock		10 14 2
		£204 1 11

PAYMENTS.

	£ s. d.	£ s. d.
Printing and Stationery		87 12 9
Illustrations		2 4 0
Attendants' Fees at Meetings		1 1 0
Secretarial Postage for 1897		1 4 1
Commission on Cheques		0 2 6
Investments and Brokers' Commission		10 14 2
Balance at Bank	£100 9 7	
,, in Office	0 13 10	
		101 3 5
		£204 1 11

Examined and compared with the vouchers and found correct. (Signed)

January 26th, 1899.

BENEDICT KITTO,
J. H. COLLINS, } *Auditors.*

LIABILITIES.

	£ s. d.
Secretarial Postage for 1898	0 16 9
Excess of Assets over Liabilities	608 2 11
	£608 19 8

The number of Life-Members on December 31st, 1898, was 46.

ASSETS.

	£ s. d.
Balance as above	101 3 5
Subscriptions unpaid	23 2 0
Stock in 2¾ Consols: £408 18s. 4d., valued at 111	453 17 11
Dividend on Stock, January 1899	2 14 4
Sale of Journal, 1898 (estimated)	12 0 0
Due for Authors' Copies	16 2 0
	£608 19 8

MEMO.—The Stock of Publications and value of the Library are not included in the above assets.

(Signed) F. W. RUDLER,

Treasurer.

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

GENERAL MEETING.

Held in the Apartments of the Geological Society, April 11th, 1899.

Mr. R. H. Scott, M.A., F.R.S., Past-President, in the Chair.

Thirteen Members and one Visitor were present.

The following papers were read:—

On Langbeinite from the Mayo Salt Mines in the Punjab: by Mr. F. R. Mallet, F.G.S.

On the Use and Advantages of a Three-Circle Goniometer: by Mr. G. F. Herbert Smith, B.A.

On a mass of meteoric iron found in Patagonia: by Mr. L. Fletcher, M.A., F.R.S.

Mr. Fletcher exhibited an etched slice of the Patagonian iron, and also a plaster-cast of the mass lent by Dr. Moreno, who first recognised the meteoric origin of the specimen.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 20th, 1899.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

Mr. William Pollard, M.A., Ph.D. was elected an Ordinary Member of the Society.

Resolved to nominate Mr. Beale, The Earl of Berkeley, Mr. Hutchinson, and Mr. Spencer to replace the four retiring Members of Council (Gen. McMahon, Mr. Barlow, Professor Miers and Mr. Pope).

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 20th, 1899.

Prof. A. H. Church, M.A. F.R.S. President, in the Chair.

Seventeen Members were present.

Digitized by Google

The following papers were read :—

1. On the Constitution of the Mineral Arsenates and Phosphates.

Part II. Plumbogummite and allied minerals : by Mr. E. G. Hartley, B.A.

2. Note on Plumbogummite: by Professor H. A. Miers, M.A., F.R.S.

3. On a Pyroxene from South Africa: by Mr. H. L. Bowman, B.A., F.C.S.

4. On the Chemical Constitution of Tetrahedrite: by Mr. G. T. Prior, M.A., F.G.S., and Mr. L. J. Spencer, M.A., F.G.S.

5. On a constituent of the meteoric iron of Youndegin, Western Australia: by Mr. L. Fletcher, M.A. F.R.S.

6. On the meteoric stones which fell at Mount Zomba, British Central Africa, on January 25th, 1899 : by Mr. L. Fletcher, M.A., F.R.S.

Mr. Bowman exhibited specimens in illustration of his paper and also a twin-crystal of sapphire from Cashmere: Mr. Fletcher showed specimens of tænite isolated from the Youndegin meteorite.

Digitized by Google

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 14th, 1899.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

The Minutes of the last Council Meeting, held June 20th, 1899, were read and confirmed.

The deaths of two Original Members, Dr. Robert Oxland and Mr. H. F. Church, were announced, and a vote of sympathy with the President on the loss of his eldest brother was passed.

Mr. Henry Jackson, B.A., B.Sc., Fellow of Downing College, Cambridge, was elected an Ordinary Member of the Society.

The draft Annual Report of Council, submitted by the General Secretary, was amended and approved.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 14th, 1899.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

Seventeen Members were present.

The Minutes of the last General Meeting, held June 20th, 1899, were read and confirmed.

Messrs. Kitto and Prior, having been nominated by the President to act as scrutineers of the voting-papers for the election of Officers and Council, reported that 41 ballot-papers had been returned, and that the List as nominated by the Council had been approved, namely:—

President.	Prof. A. H. Church, M.A., F.R.S.
Vice-Presidents.	Prof. G. D. Liveing, M.A., F.R.S.
	Mr. Hugo Müller, Ph.D., F.R.S.
Treasurer.	Mr. F. W. Rudler, F.G.S.
General Secretary.	Mr. L. Fletcher, M.A., F.R.S.
Foreign Secretary.	Prof. J. W. Judd, C.B., F.R.S.
Ordinary Members of the Council.	Mr. W. Pidgeon Beale, Q.C., F.G.S., F.C.S.
	The Earl of Berkeley, F.G.S., F.C.S.
	Prof. Grenville A. J. Cole, M.R.I.A., F.G.S.
	The Rev. H. P. Gurney, D.C.L., M.A., F.G.S.
	Mr. A. Hutchinson, M.A., Ph.D., F.C.S.
	Mr. F. R. Mallet, F.G.S.
	Mr. H. M. Platnauer, B.Sc., A.R.S.M., F.G.S.
	Mr. G. T. Prior, M.A., F.G.S.
	Mr. L. J. Spencer, M.A., F.G.S.
	Mr. J. J. H. Teall, M.A., F.R.S.
	Mr. A. E. Tutton, B.Sc., A.R.C.S., F.C.S.
	Prof. W. W. Watts, M.A., F.G.S.

Digitized by Google

A Committee, consisting of Professor Church, Mr. Scott, Mr. Beale, and Mr. Fletcher, was appointed to consider and report upon the revision of the Rules of the Society.

The following dates were announced for Meetings during the year 1900:—Jan. 23rd, April 3rd, June 19th, Nov. 13th, Anniversary.

The following Report of Council, read by the General Secretary, was proposed for adoption:—

REPORT.

The Balance Sheet for the year ending December 31st, 1898, which was issued with Number 55 of the Journal, showed that the Assets (exclusive of the Library and the Stock of the Journal) amounted to £608 19s. 8d., and the Liabilities to 16s. 9d. The number of actual Members who had compounded before December 31st, 1898, for the payment of their Annual Subscription, was 16.

During the Session 1898-9 the Society has lost two of its Original Members by death, Dr. Oxland and Mr. H. F Church, eldest brother of our President, and one Member has resigned.

On the other hand, four Ordinary Members have been elected.

The total number of Members is now 132: of these 111 are Ordinary Members, and 21 are Corresponding Members.

Four Meetings have been held during the year, all in London, and (by kind permission) in the Apartments of the Geological Society, Burlington House. The attendances at these Meetings have been 18, 25, 14 and 17 respectively.

Two Numbers of the Journal, published in April and October respectively, have been issued since the last Anniversary Meeting. To these Professor Judd and Mr. Hidden have contributed a very important paper relative to the mode of occurrence of Ruby in North Carolina: the crystals were investigated by Mr. Pratt. Mr. Herbert Smith has described a new form of Goniometer, giving special advantages for crystal measurement: the same worker has established a new mineral species, Paralaurionite. Messrs. Prior and Spencer have submitted an elaborate memoir relative to the minerals of the Tetrahedrite-Tennantite group. Mr. Prior has also given some petrographical notes on Antarctic

Digitized by Google

and Abyssinian rocks, and has added to our knowledge of the chemical composition of the niobates and titanates of the rare earths : he has also furnished the chemical analyses for a paper by Mr. Spencer dealing with the difficult minerals, Plagionite, Heteromorphite and Semseyite.

From the Oxford Laboratory, under the supervision of Professor Miers, Notes have been received relative to various minerals, more especially the incompletely known arsenates and phosphates, which are being investigated by Mr. Hartley. There have also been papers from Mr. Mallet on Langbeinite, and from Mr. Fletcher on certain meteorites.

The Society is to be congratulated on its continued prosperity.

On the motion of the President, seconded by Mr. Maskelyne, the report was adopted.

Thanks were voted to the auditors, Mr. J. H. Collins and Mr. Kitto, for their services, and the auditors were re-elected.

Votes of thanks to the Geological Society for the use of its Apartments and to the retiring Members of Council were carried with acclamation.

There being no further general business for the Anniversary Meeting, the following papers were then read :—

1. Florencite, a new hydrated phosphate of aluminium and cerium-earths from Brazil : by Dr. Hussak and Mr. Prior.

2. On Stokesite, a new mineral from Cornwall : by Mr. Hutchinson.

3. On various sulpharsenites of lead from the Binnenthal : by Mr. Solly : with analyses by Mr. Jackson.

4. On crystallised Stannite : by Mr. Prior and Mr. Spencer.

The remaining papers, namely :—

5. Mineralogical Notes : by Prof. Miers.

6. On the constitution of mineral arsenates and phosphates.

Part IV.—Beudantite : by Mr. Hartley.

7. Petrographical notes on some rock-specimens from the Little Island of Trinidad, South Atlantic : by Mr. Prior.

Owing to the lateness of the hour, were delayed to the next Meeting.

Digitized by Google

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, January 23rd, 1900.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

The Minutes of the last Council Meeting, held November 14th, 1899, were read and confirmed.

The Secretary reported the deaths of Prof. Rammelsberg, Corresponding Member, and Mr. J. R. Gregory, an original Member of the Society.

Mr. Harold Brewer Hartley, of Balliol College, Oxford, and Mr. A. Lewis Hall, B.A., of Gonville and Caius College, Cambridge, Second Demonstrator in Mineralogy at the New Museums, Cambridge, were elected to the Ordinary Membership of the Society.

The audited balance sheet for the year ending December 31st, 1899, was submitted and approved.

The Secretary was instructed to obtain information as to the practicability of printing a list of the contents of the Society's Library.

GENERAL MEETING.

Held in the Apartments of the Geological Society, January 23rd, 1900.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

Fifteen Members were present.

The Minutes of the last General Meeting, held November 14th, 1899, were read and confirmed.

The following papers were read:—

1. On the Constitution of the Mineral Arsenates and Phosphates. Part IV —Beudantite: by Mr. E. G. Hartley.

2. Mineralogical Notes: by Professor Miers.

3. Petrographical Notes on some rock-specimens from the Little Island of Trinidad, South Atlantic: by Mr. Prior.

4. A New Method of deriving the 32 Classes of Crystal Symmetry: by Mr. Barlow.

Further, Mr. Solly showed and described some specimens of Dolomite from the Binnenthal, illustrating the twinning and hemihedry of that mineral, and Mr. Hall gave an account of the crystallography of some specimens of Cornish Copper Pyrites.

Digitized by Google

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, April 3rd, 1900.

Dr. Hugo Müller, F.R.S., Vice-President, in the Chair.

The Minutes of the last Council Meeting, held January 23rd, 1900 were read and confirmed.

The Foreign Secretary reported that Professor Steenstrup, whose death was reported to the Council on Nov. 16th, 1897, was the uncle of the Corresponding Member of the Society.

The Secretary announced the death of Professor Geinitz, of Dresden, Corresponding Member of the Society.

Professor A. Lacroix, of Paris, was elected a Corresponding Member, and Mr. Ananda K. Coomára Swámy, F.G.S., was elected an Ordinary Member of the Society.

The Librarian made a statement relative to the preparation of a List of the Contents of the Library.

GENERAL MEETING.

Held in the Apartments of the Geological Society, April 3rd, 1900.

Professor G. D. Liveing, M.A., F.R.S., Vice-President, in the Chair.

Thirteen Members were present.

The Minutes of the last General Meeting, held January 23rd, 1900, were read and confirmed.

The following papers were read:—

1. Hamlinite, Florencite, Plumbogummite (Hitchcockite), Beudantite and Svanbergite as Members of an Isomorphous Group: by Mr. Prior.

2. On the optical properties of Chalybite and Diallogite: by Dr. A. Hutchinson.

3. Ægirine (and Riebeckite)-Anorthoclase rocks related to the "Grorudite-Tinguaite" group, from the neighbourhood of Adoa and Axum, Abyssinia: by Mr. Prior.

4. On the determination of the positions of points and planes after a rotation through a definite angle about a known axis: by R. W. H. T. Hudson, Esq., B.A., of St. John's College, Cambridge: communicated by Professor Lewis.

Digitized by Google

5. The chemical composition of the Mount Zomba meteorite: by Mr. Fletcher.

6. On the application of Grassmann's method of rays to the calculation of the angle between two poles: by Professor Lewis.

Professor Lewis exhibited specimens of pseudomorphous pyrites, and Professor Miers some specimens lately collected in North Wales.

Digitized by Google

Mineralogical Society—Abstract of Receipts and Payments from 1st January to 31st December, 1899.

RECEIPTS.

	£ s. d.	£ s. d.
Balance from year 1898		101 3 5
Subscriptions:—		
(1) In advance	2 10 6	
(2) Current	44 0 10	
(3) In arrear	19 1 0	
		65 12 4
Entrance Fees and Compositions		35 14 0
Sale of Publications:—		
(1) From Publishers	31 7 9	
(2) In Office	7 16 0	
		39 3 9
Authors' Extra Copies		4 3 2
Dividends on Stock		11 11 4
		£257 8 0

PAYMENTS.

	£ s. d.	£ s. d.
Printing and Stationery		90 4 6
Illustrations		7 18 5
Attendants' Fees at Meetings		1 1 0
Clerk's Fee in charge of Stock		1 1 0
Postage		2 10 10
Commission on Cheques		0 1 0
Investments and Brokers' Commission		61 11 4
Balance at Bank	£92 5 10	
,, in Office	0 14 1	
		92 19 11
		£257 8 0

Examined and compared with the vouchers and found correct. (Signed)
January 22nd, 1900.

BENEDICT KITTO,
J. H. COLLINS, } *Auditors.*

LIABILITIES.

	£ s. d.
Nil.	
Excess of Assets over Liabilities	623 17 10
	£623 17 10

The number of Life-Members on December 31st, 1899, was 49.

ASSETS.

	£ s. d.
Balance as above	92 19 11
Subscriptions unpaid	14 14 0
Stock in $2\frac{3}{4}$ Consols: £161 12s. 7d., valued at 102	470 17 2
Dividend on Stock, January 1900	3 1 9
Sale of Journal, 1899	25 5 0
Due for Authors' Copies	17 0 0
	£623 17 10

MEMO.—The Stock of Publications and Value of the Library are not included in the above Assets.

(Signed) F. W. RUDLER,
Treasurer.

Digitized by Google

Digitized by Google

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 20th, 1900.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

The deaths of the Duke of Argyll, Mr. Alex. Cruickshank, and Captain Dowler, Ordinary Members of the Society, were announced.

In regard to an application from the Royal Society relative to an International Scientific Catalogue, Mr. L. J. Spencer was nominated as a representative of Mineralogy and Crystallography for the Regional Bureau, and the Council undertook to supply the slips requisite for indexing the literature in those subjects published in Great Britain and Ireland.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 20th, 1900.

Mr. N. S. Maskelyne, M.A., F.R S., Past President, in the Chair.

Fourteen Members and One Visitor were present.

The following papers were read:—

1. On Conchite, a new variety of calcium carbonate: by Miss Agnes Kelly. (Communicated by Professor Miers.)

2. On the general determination of the three principal indices of refraction from observations made in any arbitrary zone: by Mr. G. F. Herbert Smith, B.A.

3. On Monazite from Tintagel: by Mr. H. L. Bowman, M.A.

4. On the oxidation of Pyrites by underground water: by Mr. J. W. Evans, D.Sc.

5. Petrological Notes: by Mr. G. T. Prior, M.A.

6. A quantitative determination of the action of hydrochloric acid and of soda-solution on the enstatite and felspar of the Mount Zomba meteorite: by Mr. L. Fletcher, M.A., F.R.S.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, October 9th, 1900.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

The Minutes of the last Council Meeting, held June 20th, 1900, were read and confirmed.

Digitized by Google

The resignation by Professor Miers of the Editorship of the Journal, held by him since 27th January, 1891, was announced, the resignation to take effect after the publication of the Number of the Journal now in the press. A vote of thanks to Mr. Miers for the services rendered by him in his editorial capacity was carried with acclamation. Mr. L. J. Spencer was appointed to succeed Professor Miers as Editor of the Journal.

Resolved to nominate Mr. J. H. Collins, Professor Lewis, Professor Miers and General McMahon to replace the four retiring Members of Council (Professor Cole, Dr. Gurney, Mr. Mallet and Mr. Prior).

The draft Bye-laws submitted to the Council on behalf of the Committee (Professor Church, Mr. Beale, Mr. Scott and Mr. Fletcher) appointed at the last Anniversary Meeting, were amended and approved: the General Secretary was instructed to send a copy to every Ordinary Member of the Society, and to give notice that the substitution of the Bye-laws for the present Rules would be proposed at the Anniversary Meeting.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 13th, 1900.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

The Minutes of the last Council Meeting, held October 9th, 1900, were read and confirmed.

The deaths of Professor Waage, Corresponding Member, and Mr. Greenwell, Original Member, were announced.

Mr. F. N. A. Fleischmann was elected an Ordinary Member of the Society.

The following were selected as the dates of meeting for the year 1901: —January 22, April 2, June 18 and November 12, the latter to be the Anniversary Meeting.

The draft Annual Report of Council, submitted by the General Secretary, and the proposed Bye-laws of the Society, were amended and approved.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 13th, 1900.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

Eighteen Members were present.

Digitized by Google

The Minutes of the last General Meeting, held June 19th, 1900, were read and confirmed.

Messrs. Evans and Spencer, having been nominated by the President to act as scrutineers of the voting papers for the election of Officers and Council, reported that 40 voting papers had been returned, and that the List as nominated by the Council had been approved, namely:—

President.	Prof. A. H. Church, M.A., F.R.S.
Vice-Presidents.	Prof. G. D. Liveing, M.A., F.R.S. Mr. Hugo Müller, Ph.D., F.R.S.
Treasurer.	Mr. F. W. Rudler, F.G.S.
General Secretary.	Mr. L. Fletcher, M.A., F.R.S.
Foreign Secretary.	Prof. J. W. Judd, C.B., F.R.S.
Ordinary Members of the Council.	Mr. H. M. Platnauer, B.Sc., A.R.S.M., F.G.S. Mr. J. J. H. Teall, M.A., F.R.S. Mr A. E. Tutton, B.Sc., A.R.C.S., F.R.S. Prof. W. W. Watts, M.A., F.G.S. Mr. W. P. Beale, Q.C., F.G.S., F.C.S. The Earl of Berkeley, F.G.S., F.C.S. Mr. A. Hutchinson, M.A., Ph.D., F.C.S. Mr. L. J. Spencer, M.A., F.G.S. Mr. J. H. Collins, F.G.S. Prof. W. J. Lewis, M.A., F.C.S. Lieut.-Gen. C. A. McMahon, F.R.S. Prof. H. A. Miers, M.A., F.R.S.

The following Report of Council was read by the General Secretary:—

REPORT.

The Balance Sheet for the year ending December 31st, 1899, which was issued with Number 57 of the Journal, showed that the Assets of the Society (exclusive of the Library and the Stock of the Journal) amounted to £623 17s. 10d., and that there were no Liabilities. The number of actual Members who had compounded before December 31st, 1899, for the payment of their Annual Subscription, was 49; the value of the Stock invested in the names of the Trustees of the Society was then £470 17s. 2d.

During the Session 1899-1900 the Society has lost four Ordinary Members and one Corresponding Member by death, and three Ordinary Members have been removed from the List for non-payment of their subscriptions; on the other hand four Ordinary Members and one Corresponding Member have been

Digitized by Google

elected. The total number of Members is now 128; of these 107 are Ordinary Members and 21 are Corresponding Members.

Four Meetings have been held during the year, all in London, and (by kind permission) in the Apartments of the Geological Society, Burlington House. The attendances at these Meetings have been 17, 15, 13 and 15, respectively.

Only one Number of the Journal, published in July, has been issued since the last Anniversary Meeting. To this Professor Miers and Mr. E. G. Hartley contributed papers relative to Hitchcockite, Plumbogummite and Beudantite, belonging to the arsenate and phosphate division of minerals. Dr. Hussak and Mr. Prior described a new phosphate to which they gave the name of Florencite, and Mr. Prior further suggested that Florencite, Hamlinite, Plumbogummite (Hitchcockite), Beudantite and Svanbergite are all of them members of the same Natural Group. Mr. Hutchinson described a new mineral species, Stokesite, remarkable as being a silicate of calcium and tin. Further, Mr. Solly and Mr. Jackson gave an account of the various sulpharsenites of lead from the Binnenthal, and Mr. Prior a description of some remarkable rocks from Abyssinia. For the Abstracts in the same Number the Society is again indebted to the industry of Mr. Spencer and Mr. Herbert Smith.

The Council regrets to report that with the issue of the forthcoming Number Professor Miers will retire from the Editorship of the Journal, the duties of which post he has now undertaken for ten years to the gratification of the Society and the satisfaction of the authors of papers. The Council is glad to report that Mr. Spencer is willing to undertake the duties, and has been appointed Editor.

At the last Anniversary Meeting a Committee, consisting of Prof. Church, Mr. Scott, Mr. Beale and Mr. Fletcher, was appointed to consider the Rules of the Society; as a result of their deliberations a set of Bye-laws in which the experience of a quarter of a century is incorporated has been prepared for recommendation to the Society at this Anniversary Meeting.

On the motion of the President, seconded by the General Secretary, the Report was adopted.

Digitized by Google

Thanks were voted to the auditors (Mr. J. H. Collins and Mr. Kitto), to the Geological Society for the use of its Apartments, to the retiring Editor of the Journal after 10 years of service, and to the retiring Members of Council (Prof. Cole, Dr. Gurney, Mr. Mallet and Mr. Prior).

The Bye-laws submitted for the consideration of the Society by the Committee appointed at the last Anniversary Meeting and by the Council were amended.

On the motion of Mr. Beale, seconded by General McMahon, it was resolved that the Bye-laws as thus amended be substituted for the existing Rules: the General Secretary was instructed to insert a copy in the Minutes, and to publish a copy in the next Volume of the Journal.

The following papers were then considered:—

An improved form of Three-Circle Goniometer; by Mr. G. F. Herbert Smith, B.A.

A simple proof of the rationality of the anharmonic ratio of four faces of a zone; by Mr. Harold Hilton, B.A. (Communicated by Professor Miers.)

Sulpharsenites of lead from the Binnenthal: Part II, Rathite; by Mr. R. H. Solly, M.A.

Digitized by Google

LIST OF SERIALS IN THE LIBRARY OF THE MINERALOGICAL SOCIETY.

Librarian: Prof. W. J. Lewis, The New Museums, Cambridge.

BOUND VOLUMES.	UNBOUND PARTS.	MISSING.
Bristol Naturalists' Society, Proceedings	From Vol. III, 1880 to VI, 1891	—
Cornwall, Royal Institution, Journal	IX, 1886 to XIII (4), 1898	Part 37, 1891; Part 39, 1893
Edinburgh Geological Society, Transactions	VII, 1894–9	—
Glasgow Geological Society, Transactions	X, 1892–6	—
Mineralogical Magazine (2 copies), I, 1876 to X, 1894	XI, 1895; XII, 1900	—
Naturalist, The	1885 to 1899	—
North of England Institute of Mining and Mechanical Engineers	XXVI, 1876 to XLIX, 1900	—
Yorkshire Naturalists' Union, Transactions	I, 1878 to XXI, 1898	IX to XIX
Australian Museum (Sydney), Records	I, 9, 1891 to III, 7, 1900	—
Australian Museum (Sydney), Reports	1882 to 1899	—
New South Wales, Royal Society, Journal and Proceedings	IX, 1875 to XXXIII, 1899	XIII, 1879; XIV, 1883; XVII, 1887
New South Wales, Department of Mines, Annual Reports	1876 to 1899	1878, 9; 1882, 3; 1885; 1887–9; 1897
New South Wales, Mines and Mineral Statistics	1875 to 1880	—
New South Wales, Geological Survey, Records	II, 1890 to VI, 1900	—
New South Wales, Geological Survey, Memoirs	Nos. 1 to 9	No. 6
New South Wales, Technological Museums Reports	1883 to 1890	1887
Victoria, Mineral Statistics	1876 to 1881	—
Victoria, Reports of Chief Inspector of Mines	1874, 5; 1881	—
Victoria, Reports of Mining Surveyors	March 1875 to Sept. 1882	—
New Zealand, Geological Survey, Reports, 1874 to 1878	—	—
Canada, Geological Survey, Reports, 1894 to 1897	1879 to 1893	—

Digitized by Google

BOUND VOLUMES.	UNBOUND PARTS.	MISSING.
Nova Scotian Institute Nat. Sci., Proceedings and Transactions	IV, 4, 1877 to X, 1, 1899	V, 2 and 4; VI; VII, 1, 2
American Chemical Journal, II, 1880 to XVII, 1895	I, 1879; XVIII, 1896 to XXI, 1899	XVIII, 9; XIX, 1
American Geologist	XVII, 1896 to XXV, 1900	—
American Journal of Science, XIII [iii] 1877 to II [iv], 1896	III, 1897 to IX, 1900	—
Journal of Geology	V, 1897 to VII, 1899	V, 1
California, Annual Reports of the State Mineralogist	IV, 1884 to XIII, 1896	—
Colorado Scientific Society, Proceedings	I, 1883 to III, 1889	II, 1; III, 1
New York Academy of Sciences, Annals	1881–3	—
New York Academy of Sciences, Transactions	1881–3	—
Philadelphia Academy of Natural Sciences, Proceedings, 1877 to 1884	—	1881; 1883
Smithsonian Institution, Annual Reports, 1881 to 1895	—	—
United States Geological Survey, Annual Reports, II, 1880 to XX, 1899	—	—
United States Geological Survey, Bulletins, I, 1883 to CXXII, 1894	XVIII to XLVI; LXV to LXX; LXXXVII to LXXXIX; CXXIII to CLXII, 1899	—
United States Geological Survey, Mineral Resources, 1883 to 1893	—	—
United States Geological Survey, Monographs, I, 1890 to XXXVIII, 1899	—	—
United States Geological and Geographical Survey, for 1878 (Wyoming and Idaho), 1883	—	—
France, Société Minéralogique, Bulletin, I, 1878 to X, 1887; XVIII, 1895	XIX, 1896 to XXI, 1898	XI to XV; XVI, 8; XVII, 6 to 8; XXI, 3 to 7; XXII, 1899
Luxembourg, Publications Institut Grand-ducal (Soc. Sci. Nat.)	II, 1854 to XXIV, 1896	VI, 1863; XXI, XXII, 1892–3
Belgique, Société Géologique, Annales, I, 1874 to XXI, 1894	XVIII; XIX; XXII, 1894 to XXV, 1898	XIX, 1
Giornale di Mineralogia (Sansoni), I, 1890 to IV, 1893	V, 1894	Fasc. III, 1894
Rivista di Mineralogia e Crist. (Panebianco)	XVII, 1897 to XXIV, 1900	—
Il Nuovo Cimento, I [iv] 1895 to II [iv] 1895	III [iv], 1896 to X [iv], 1899	III, 2, 1896

Digitized by Google

BOUND VOLUMES.	UNBOUND PARTS.	MISSING.
Atti R. Accad. Lincei, Rendiconti, I, 1885 to VI, 2, 1890	IV, 2	—
Atti R. Accad. Lincei, Transunti, VII, 1883 to VIII, 1884	V, 1881	VI, 1882
Atti Soc. Toscana Sci. Nat., Memorie, III, 1877 to XIV, 1895	VIII, 1, 1886; XV, XVI	VIII, 2
Reale Comitato Geologico d'Italia, Bollettino, VIII, 1877 to XI, 1880; XVI, 1885 to XXII, 1891; XXIV, 1893 to XXVI, 1895	VII, 1876; XII, 1881 to XV, 1884; XXIII, 1892; XXVII, 1896 to XXX, 1899	—
Rendic. Accad. Sci. Napoli, III, 1889 to VIII, 1894; I [iii], 1895	II, 1888; IV, 1890; II [iii], 1890 to V [iii], 1899	II [ii], 3 to 8; IV [ii], 5; V [iii], 5
Mineralogische und Petrographische Mittheilungen, I, 1878 to XV, 1895	XVI, 1896 to XIX, 1899	—
Vienna, Geolog. Reichsanstalt, Jahrbuch, XXVII, 1877 to XLIV, 1894	XLV, 1895 to L, i, 1900	—
Vienna, Geolog. Reichsanstalt, Verhandlungen	1877 to 1899	—
Vienna, Naturhist. Hofmuseum, Annalen, I, 1886 to IX, 1894	X, 1895; XI, 1896	—
Zeitschrift f. Krystallographie und Mineralogie, I, 1877 to XXVI, 1896	XXVII, 1897 to XXXI, 1900. Rep. XI to XX; XXI to XXX	—
Zeitschrift f. Naturwissenschaften, Halle, XLIX, 1877 to LXVI, 1893	LVI, 1883; LXVII, 1894 to LXXI, 1898	—
Finland, Commission Géologique, Bulletin	I, 1895 to VIII, 1898; XI, 1900	VI; IX; X, 1899
Finland, Geol. Undersökning, Beskrifning till Kartbladet, X to XVII	I; II; XXII to XXIX; XXXV	III; IX
Upsala, Geological Inst. Univ., Bulletin, I, 1893–4	II, 1895 to IV, 1900	—
Upsala, Univ. Min.-Geol. Instit., Meddelanden, I to XV	XVI to XXII	—
Grönland, Meddelelser om, I, 1879 to XIII, 1890	XIV to XXI; XXIII, 1899	XXII, 1899
Mexico, Memorias y Revista Soc. Cient. "Antonio Alzate"	I, 1887 to III, 1890	I, pp. 363 to 418; II, 1889
S. Paulo, Bol. Com. Geog. e Geol. I, 1889 to IX, 1893	X, 1894 to XIV, 1897	XI
S. Paulo, Bol. Com. Geog. e Geol., Dados Climat., 1887 to 1892	1893 to 1897	—
Argentina, Anales Soc. Cient., VIII, 1879 to XL, 1895	XI, XII, 1881; XXIX to XXXIV; XLI, 1896 to XLIX, 1900	—

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

BRANNER GEOLOGY LIBRARY
549.05
M66
12
1898-1900

Return this book on or before date due.

NON-CIRCULATING

~~MAR 15 1987~~
FEB 16 1987

Digitized by Google

Digitized by Google